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THE PHILOSOPHY

OF

COMMON THINGS.

FIRST SERIES.

The very law that moulds a tear,
  And bids it trickle from its source;
That law preserves the earth a sphere,
  And guides the planets in their course.

ROGERS.

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CHAPTER I.

MATERIALS FOR BUILDING.

STRATIFIED ROCKS—GRANITE—SLATE—LIMESTONE—MORTAR.

Among the common objects it is now proposed to notice, we shall here refer to the materials which our great Creator has provided for the erection and decoration of buildings, for various purposes. Wood was probably the earliest material employed in building, but its liability to decay, and want of elegance, caused the introduction of brick and stone. The character of the stone was not at first considered, but it was soon discovered that many kinds, which were otherwise suitable, were not able to resist the action of the atmosphere.

Since geology has risen into notice among the sciences, the attention of many intelligent men has been directed to the subject, and much important information has been collected. In endeavouring to explain the character and natural position among rocks of some stones used in building, it will be necessary to refer to the science from which our knowledge is chiefly obtained, and to illustrate incidentally its classification. M. d'Aubuisson, a celebrated French professor, says, "The principal object which geology has in view, is a knowledge of the mineral masses, whose assemblage composes the solid portions of the terrestrial globe. It considers the mineralogical composition, structure, and extent of each of these masses, the circumstances of their superposition one to the other, and the different relations subsisting between them, every thing which relates to their formation, and to the changes which they have undergone."

The crust, or covering of the earth, is composed of a great variety of substances. The majority of these are arranged in beds, or strata. By a stratified rock is meant, one which is divided by parallel seams, extending throughout the mass, the length and breadth being greater than the thickness. Since these strata were

formed, many violent agents have acted upon them, causing a variety of contortions, to which all the appearances they now present may be traced.

Granite is a rock frequently used in building, and generally known in some of its common varieties. The word granite is derived from the Latin term, *geranites*, which, however, the Romans applied to every granular stone. Tournefort, the celebrated naturalist, was the first modern author who made use of the word.

The minerals which commonly enter into the composition of granite are quartz, feldspar, mica, and hornblende; and two or more of these are necessary to compose it. Feldspar is, generally, the most abundant; but this mineral, as well as all others which enter into the composition, varies in its proportion, and is sometimes altogether wanting. A granite of Mont Blanc is composed of feldspar, quartz, and chlorite. The writer observed one in Aberdeenshire which consisted of feldspar and hornblende; and another in Perthshire, consisting of quartz, feldspar, and actinolite. All the varieties are not equally suited for building materials: those are most durable which have the least quantity of feldspar, and the greatest quantity of quartz. Feldspar is very liable to decomposition by the

atmosphere, and in some parts large masses of the rock are wasted from this cause.

The Egyptians used granite in many of their structures, and a most durable kind, as may be proved by an examination of the rock, as well as from the fact, that they have resisted the influence of destroying agents for many centuries. The granite used in London Bridge is an excellent building material; but there are instances in which a most improper variety has been employed in the metropolis.

Granite belongs to that series of rocks called primary, or, more properly, crystalline. They are the lowest of all the mineral masses with which we are acquainted; but are frequently observed in situations that prove they have been acted upon by violent disturbing forces. They sometimes form mountains of great elevation, and pierce through rocks more recently formed than themselves, tilting them on their edges. In such cases, the recent rocks, generally stratified, may be seen on the opposite sides of the elevation, presenting an appearance not much unlike that of the gable end of a roof.

Granite was once considered the oldest rock, the foundation of all others; but this is not its universal position. Werner arranges the granites in three classes: first, the primitive, or that

below which no others have been found; secondly, that which traverses veins; and thirdly, that which rests on primitive rocks. In Iona, Barra, Tirey, and many others of the Western Isles, it traverses gneiss, and greatly contorts the mass. At St. Gothard, it rests on mica slate; at Kielwig, in Norway, on clay slate; at Altenburg, on gneiss. From these facts, it is evident that all the granites are not of the same relative age. Yet it appears from what is known of the Swedish, Swiss, and Tyrolian Alps, and of the Apennines, and Andes, that some of the highest peaks of continuous chains are formed of granite. So, also, it is evident, from observations made on the surface of the earth, and in deep mines, that it is the base of all the continents.

The colour of granite depends on the preponderance of some one or more ingredients. It is coloured black by hornblende, or black mica; dark red, or grey, by feldspar: but as the proportions of the ingredients, and the changes they undergo, are numerous, the colours must be equally variable.

In working granite for architectural purposes, it is found there is a plane in which it is more easily separated than any other; this is called the line of cleavage. The miner, from constant practice, is able to fix upon this with great

precision. A knowledge of this fact has, in some degree, prompted the inquiry, Is granite stratified? The answers given to this question are so opposed to each other, that it seems hardly necessary to make any remarks on the subject, except as they may tend to induce a careful regard to the origin and nature of natural appearances.

Gruber thought the stratification of granite so evident in the Riesengeberg, or Giant's Mountain, that he questioned the sanity of the man who could see what he had seen, and come to an opposite conclusion. Dr. Mitchel traced it for fifty miles, and Professor Jameson for one hundred and fifty. M. von Buch, however, strained his eyes in vain, and after a diligent search, he gave up the pursuit in despair. Dr. Hutton asserts, he never saw a stratified granite; and a German philosopher, of equal celebrity, tacitly confesses that he never saw one unstratified. We will not attempt to separate so many entangled opinions; it is only necessary to say, that further observation has proved, to the satisfaction of nearly all geologists, that, although granite has a line of cleavage, it is not a stratified rock.

The rocks associated with granite are gneiss, mica slate, quartz, clay slate, and primitive

limestone. Gneiss only differs from granite in its slaty structure, and the parallel position which generally pervades its mica. It is one of the most extensively distributed rocks of its period, and is very metalliferous. It is not, however, used for architectural purposes, and, consequently, does not now come under our consideration: the same remark applies to mica slate, and quartz.

Clay slate, sometimes called argillaceous schist, consists of silex, or flint, alumina, or clay, and oxide of iron. It is always stratified, and has a slaty structure. Snowdon, Plinlimmon, and considerable districts around them, are composed of it; and in Cumberland, Westmoreland, and Cornwall, it is abundant. Of this rock there are many varieties, among which we may enumerate roofing slate, and drawing slate.

Primitive limestone is generally of a yellowish white, greyish, or greenish colour: its structure is always granular. That which is associated with mica slate and clay slate is generally less crystalline than that found in granite and gneiss. It frequently contains beds of metal, especially magnetic iron ore, pyrites, blende, and gold. The finest statuary marbles are primitive limestone. A beautifully white marble is found in the gneiss of Skye; and the steps to St. Paul's

Cathedral, in London, were taken from a bed at Poolvash, in the Isle of Man.

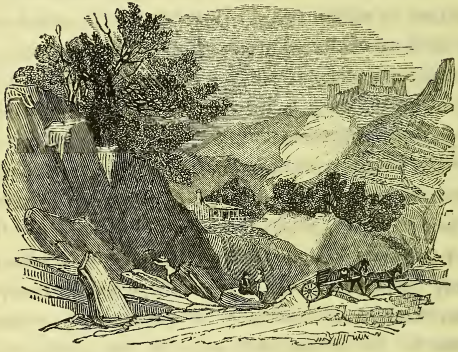
Above the primitive rocks there are many different kinds of the mineral masses, used for building purposes. That series which lies immediately upon the primitives, was called the transition, because, although they have a great analogy to the rocks on which they rest, they differ from them in frequent alternation with rocks of other kinds. They have been otherwise distinguished as the lowest rocks in which organic remains have been found.

Above the transition rocks there is another class, called the secondary. Some writers, from the difficulty of determining the precise characters of the transition rocks, wished to incorporate them with the primitive, or secondaries; and there was much discussion as to which they should be assigned. "Some geologists," says d'Aubuisson, "have thought that the transition class might be suppressed altogether; but I am very far from agreeing with them: the idea of Werner in establishing it was very happy. It relates to an epoch when a revolution took place in nature, which, from the numerous indications we witness, is, perhaps, the most violent of all those which occurred during the formation of the mineral shell of the globe." Modern geologists have,

however, formed a different arrangement: they divide all rocks into groups, according to their relations. That series immediately above the primitives, is called the grauwacke group; and here we find several rocks used for building purposes.

Clay slate is one of the principal rocks of the grauwacke group. By the Germans it is called thon scheiffer; and, in imitation of them, English geologists have designated it clay slate. Its colours are as numerous as its varieties; they are chiefly grey, green, or blue. The endless peculiarities in the appearance of rocks is easily accounted for, when we remember that the smallest alteration in the quantity or character of the constituent parts of any substance, decidedly alters the appearance of the mass. When silicious, that is, flinty matter, abounds in slate, it passes into flinty slate; when magnesia preponderates, into chlorite slate; and when minute particles of quartz unite with chlorite slate, we have whetstone slate, which is more or less valuable for hones, according to the minuteness of the particles of quartz. The fine varieties of slate are usually found embedded to rocks of a coarser texture; and some quarries of it are extensively worked in many counties of England and Wales. When carbonaceous matter is present, the slate is smooth and fit for drawing,

that being the best in which there is the greatest proportion of carbon.



Slate Quarries near Harlech, Merionethshir

Slates are now commonly employed to cover the roofs of buildings, and are admirably adapted for this purpose, both by their strength and appearance. The Welsh and Westmoreland slates are generally preferred, being of a much better colour than any of the others; but many of those obtained in Devonshire are well suited for the same purpose. When taken from the quarry, the slates are cut into various sizes, and receive from the workmen different names, such as duchesses, countesses, and ladies. Slates are sold by the great hundred, that is, one hundred

and twenty, and when placed on a roof are estimated by the square.

The following are the names and sizes of the slates, as brought into the market: Doubles are, 1 ft. 2 in. by 6 in.; ladies, 1 ft. 3 in. by 8 in.; countesses, 1 ft. 10 in. by 11 in.; duchesses, 2 ft. 2 in. by 1 ft. 3 in.; rags and queens, 3 ft. 3 in. by 2 ft. 3 in.; imperials, 2 ft. 8 in. by 2 ft. 2 in.

The mountains composed of slate rocks are not so rugged or steep as those of granite. They generally present a pleasing acclivity. To a person unacquainted with geology this remark may appear strange, but an experienced observer can, from an examination of the scenery around him, frequently determine the nature of the rock of which the district is composed. The slate rocks have also a value from the quantity of metallic ore found in them. Copper and lead are the most abundant in England, but nearly all the other metals are occasionally found.

Associated with the slate rocks, there is an exceedingly interesting and important bed, called the transition limestone. It yields the greater part of our statuary marble, the other kinds being frequently too coarse for the chisel. The mineral characters of transition limestone greatly depend on the rock with which it is associated. Its prevailing colours are grey, brown, red, and

black; but it frequently presents a variegated appearance. Nearly all the Italian marbles belong to the same series. Marble is chiefly used for chimney-pieces, but in some costly buildings the stairs are made of the same material. Many organic remains, or animals in a fossil state, are found in some transition limestones. When the marble is cut and polished, the internal structure of these animals is often very beautifully shown. The transition limestone is best developed in Ireland, but may also be studied in the south of Scotland, and in Devonshire.

A series of rocks, called the carboniferous group, rests upon the grauwacke series, and in it we find a rock called the carboniferous, or mountain limestone, which is often used as a marble. It has an imperfectly crystalline texture, and is generally of a grey, greyish white, or yellow colour. On account of the variety of its fossils, the beauty of its caverns, and the unspeakably romantic scenery of the districts where it is the superior rock, we may consider it the most interesting of all the calcareous deposits. The lead mines of Northumberland, Yorkshire, Derbyshire, and other counties, are situated in mountain limestone.

The rocks of the red sandstone group, which

lies upon the carboniferous, are not of much use in building. The predominant colour of the principal rock is a strong objection to it, were there no other ; but its composition is such as to offer no inducement to use it.

The oolitic group is still higher in the series, and from it we obtain the most valuable building stones. The Bath stone, frequently used for large buildings in the metropolis, and other wealthy towns, belongs to this group ; and in the city whose name it bears, all the houses are formed of it. The following description is given by Mr. Conybeare of the great oolite, and, as he states that it was principally copied from Mr. Smith's account, the passage is quoted :—" This is, both in thickness and utility, by far the most important of the British oolites, it consists of a stratified, calcareous mass, varying in thickness from 130 to more than 200 feet : softer and harder beds (the former characterised by those concretions which gave name to this series of rocks, the latter exhibiting them more rarely and obscurely) alternate in this mass of strata. The former afford the freestone which renders this rock so valuable ; but these strata vary much, both in thickness and quality, even in quarries in the same neighbourhood. The Kettering freestone of Northamptonshire, is rendered

extremely beautiful by the distinctness of its oolitic structure: that of Bath has generally a finer grain: this has been employed in the repairs of Henry the Seventh's Chapel at Westminster. St. Paul's was built principally from the quarries about a mile north of Burford, in Oxfordshire. Fragments of comminated shells may be discovered in all the varieties. The colour of the freestone beds is generally white, with a light cast of yellow. The upper beds, in which the shells are more distinct, and which afford indifferent freestone, cannot be distinguished from the forest marble."

The Portland stone, well known from its frequent use in building, also belongs to the oolitic group. It is a yellowish-white, calcareous freestone, with a small quantity of silicious sand intermixed. That obtained from the islands of Purbeck and Portland, which has no oolitic character, is much used in London. It is considered a hard and durable stone, well suited for building purposes.

The Purbeck stone belongs to the Wealden group, but lies upon the Portland oolite. The Purbeck beds consist of argillaceous limestones, commonly used in London as paving stones, and schistose marls. Many of these beds contain a great number of fossils, while others are

entirely without, and are used for architectural purposes. The Purbeck marble, formerly employed for columns and monuments in our churches, was one of the uppermost of the beds, but is now never brought into the market. In appearance it greatly resembles that stone which is called the Petworth marble.

There are many other rocks situated above those now described, that may be occasionally used for architectural purposes; but they are seldom, if ever, introduced into the market, and therefore need not be further alluded to.

The choice of suitable materials for building is evidently of the greatest importance; but it is too little considered by those who have the superintendence of public works. Something more is required than an acquaintance with the names of rocks; for a rock may be suited as a building material when used in one situation, and not so in another. So, also, a rock obtained in one place may be adapted for a particular purpose, but one of the same name from another locality may have altogether different properties. Granite is an instance of this. There are some granites which, although very hard and exceedingly difficult to work when first taken from the quarry, cannot be considered as proper materials for building. "Rocks which contain compact

feldspar," says M. De la Beche, "are very often durable. Some of the elvans, as they are provincially termed, of Cornwall, seem to be particularly durable when exposed to atmospheric influences: for some of the old and external carved stonework of the churches constructed with this material in that part of England, is as perfect as when first put up."

That rocks which are durable in some situations, are not necessarily so in all, may be proved from a variety of instances. A mineral substance which does not suffer under the influence of the weather, may be quickly destroyed if constantly exposed to the action of water. And another, which may be able to resist the influence of either air or water, may be altogether unsuited to a situation in which it will be alternately wet and dry.

In choosing a stone for any particular purpose, it is necessary to consider the character of those agents which act upon it in its place, and the influence they exert on its superficial character. The observer must then endeavour to determine, by experiment or other observations, the effect of different agents, if he requires it for a situation dissimilar to that in which it was discovered. Perhaps, an architect may require a stone which can be used in a situation where

the water and air will be alternately acting upon it, and he may find on a sea-coast a rock, which is in one part exposed to the air, and in another to the ocean, and still able to resist the influence of the one and the other. Would it be safe to use the stone for the purpose required? By no means. Decomposition may not be produced by either the water or air acting separately; but when they act alternately upon the same mass, the destruction may go on rapidly

The oolites are greatly valued by those engaged in preparing materials for building, because they are easily worked when first brought from the quarry, and afterwards become very hard, on exposure to the atmosphere. Though this may be the case, it is by no means certain they are durable. When the stone is taken from the quarry, it contains a great quantity of moisture, causing it to be easily cut or carved: from which circumstance it derives its name, freestone. Now, there are some of these which absorb moisture as freely as they evaporate it; and such are evidently most unfit for architectural purposes, especially in climates where there are frequent changes of temperature, for there is no cause more active in destroying rocks than frost.

M. De la Beche has shown the importance of selecting stones for artificial harbours, bridges,

and breakwaters; those used in different parts being suited to the nature and influence of the agents acting upon them. "The weight of a stone," he says, "is an important consideration, since the greater the weight in the same bulk, the greater the resistance to removal from the blow of a breaker, other things being equal." "An observer, therefore," says the same author, "should ascertain the specific gravity of a stone he may be desirous of employing. Several kinds of stone, otherwise equally good, may vary much in this respect; so that a pier of given dimensions may differ considerably from another in weight, according to the materials employed." The necessity of geological knowledge to those engaged in the art of building, must be evident from these remarks.

The composition of all rocks was, in some degree, dependent on chemical action. There is no single mineral mass which consists of a simple indecomposable substance. One example may be taken. Limestones, marbles, and chalk, are composed of carbonate of lime, which is by far the most abundant product in nature. Carbonate of lime consists of lime and carbonic acid, as its name intimates. Lime has a very powerful attraction for carbonic acid. Mix lime and water, so as to bring the compound to the consistency

of paste, and invert over it a bottle containing carbonic acid, a rapid absorption will commence. The same fact may be proved in another way. Take a bottle of transparent lime-water, and connect it with a bottle containing the same gas; the lime-water will soon become milky from the formation of carbonate of lime.

But although there is this great attraction, or affinity, between the two substances which form carbonate of lime, they may be readily separated. If diluted muriatic or sulphuric acid be poured upon a piece of marble or chalk, the carbonic acid gas instantly escapes, and may be collected over water. This being the case, the architect must be careful not to use the mineral in any situation where it will be exposed to the action of an agent which has the power of decomposing it; and the same care must be taken with all other substances.

The process of sawing and polishing marbles and stones must have been observed in every stonemason's yard. It will not, therefore, be necessary to occupy space with a description; but, in conclusion, a few remarks may be made upon the cements, by which stones are united together in buildings.

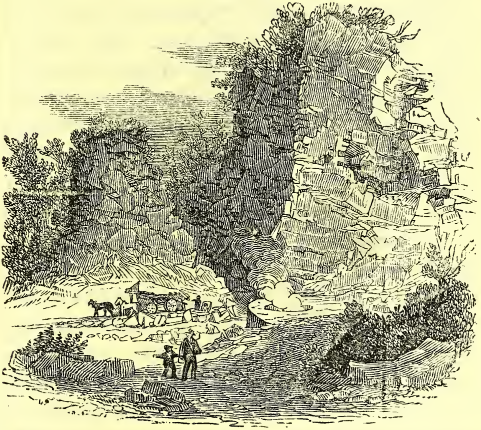
Mortar, which is the most common of all cements, is chiefly formed of lime, chalk, marble,

stone, or some other carbonate of lime broken into pieces. One process is called winning. The

Winning Lime.

labour thus given detaches pieces from the mass, to be piled up in the kiln with alternate layers of coal. A large fire is then lighted, and the whole raised to a white heat, which drives off the carbonic acid and water, leaving a tolerably pure lime. Mortar is formed of lime and sand, which are brought into the consistency of paste by the addition of water, and thoroughly mixed. The amount of sand taken up and mixed with the lime, will depend upon the purity of that substance.

A good lime will take more sand than one of inferior quality. The chemical changes effected



Lime Quarry and Kiln.

in the manufacture of mortar, and producing its cementing qualities, are varied. The lime first enters into chemical combination with a portion of water, and thus forms what is called a hydrate of lime. This new compound has an attraction for the sand, by which the mixture is made more cohesive. After the mortar has been standing for a long time, it absorbs a portion of

carbonic acid from the atmosphere, and it then becomes as hard as the stone from which the lime was first produced.

Although mortar is a very proper material to be used in all those cases where the brick or stone work is to be only exposed to the atmosphere, it is unsuited to any situation where the work is under water. Parker's roman cement is then used. This cement is made from the nodules of sulphate of lime found on the seacoast of Sheppy, Harwich, and other places. These stones, when burned and ground, yield a cement, which has the property of setting under water. It is now extensively employed in all parts of this country to cover the fronts of buildings, for which it is admirably adapted, as it greatly resembles stone when set. Good cement will take two parts of sand; and about forty bushels of cement, with its proportionate quantity of sand, will do a rod of brickwork. Putty is sometimes used for the purpose of fastening together small pieces of stone and marble. Dutch tiles, which were at one time placed on the chimney sides, are always set with this material.

Such, then, are some of the materials of which lofty edifices are reared, often at a large expenditure of skill and property. And yet, "surely man at his best estate is altogether vanity."

Splendid houses have been built and furnished, and on the very day when they have been ready to receive their elated proprietors, the intended tenants of an earthly palace have been called down to the "narrow house," the "house appointed for all living." Lawns and pleasure grounds have been planned with lively interest, and laid out with exquisite taste and beauty; but the eye of their short-lived possessor has given them but one survey, and then has closed in death. And even where the earthly course has reached the full age of man, it has still been like the passage of the shuttle in the weaver's loom, or of an eagle hastening to its prey. A splendid mansion is but the tarrying place for a season of successive generations, gathered one after another to the sepulchres of their fathers. Soon, very soon, must our earthly house of this tabernacle be dissolved, 2 Cor. v. 1.

It becomes us, therefore, often to reflect on a more durable edifice. Addressing the Ephesians, the apostle Paul says, "Ye are no more strangers and foreigners, but fellow citizens with the saints, and of the household of God; and are built upon the foundation of the apostles and prophets, Jesus Christ himself being the chief corner stone; in whom all the building fitly framed together groweth unto an holy temple in the Lord: in

whom ye also are builded together for an habitation of God through the Spirit," Eph. ii. 19—22. Such are the privileges of all, whether Jews or Gentiles, who build all their hopes of acceptance with God, and eternal happiness, on that Divine Redeemer, who is "the chief corner stone," and who thus form the spiritual temple, which was typified by the altar and the sanctuary. According to the counsel of the Divine Architect, it grows up to be a holy temple in the Lord, being dedicated to his glory, the place of his special presence and favour, and the object on which he dwells with ineffable complacency. How important is the question, then, Am I "a living stone" of this spiritual structure? If I am not, I stand exposed to the wrath of the Almighty: if I am, all things shall work together for my good, and "the sufferings of this present time are not worthy to be compared with the glory that shall be revealed in us," Rom. viii. 18, 28.

CHAPTER II.

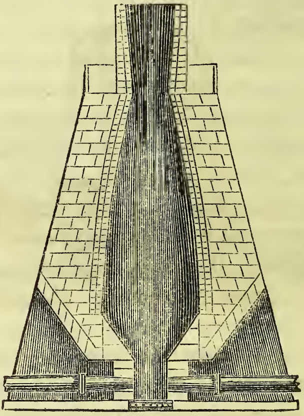
IRON.

METEORIC STONES—CAST-IRON—WROUGHT-IRON—STEEL.

Of all the substances with which we are made acquainted by geology and chemistry, none are more important to us than iron. In various states it is employed in the construction of utensils and instruments required in culinary operations. Saucepans, kettles, and pans are frequently made of cast-iron ; bolts, italian-heaters, and other things, of wrought-iron ; and fire-irons of steel. A short account of this metal, and the processes it undergoes to fit it for manufacture, will not, therefore, be unimportant.

Iron is almost universally diffused through nature : it has been detected in plants and animal fluids ; it forms the colouring matter of many substances ; and is extensively distributed in some parts of the mineral series. It is a malleable metal, so ductile that it may be beaten out into a wire finer than the human hair, and may be permanently united, or welded, by forging.

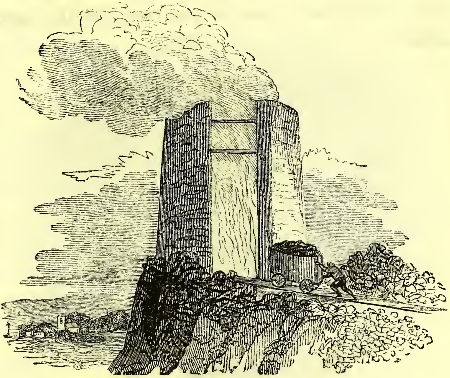
The ores of iron are numerous. The meteoric stones always contain a proportion of iron: one of these fell near Agram, in Croatia, in the year 1751, and was found to consist of 96½ per cent. of iron, and 3½ of nickel. A mass of the same kind found in South America, and supposed to weigh 30 tons, consisted of 90 parts of iron; and that which has been observed in the desert of Zahara, has 96 per cent. of the same metal.



Section of a Smelting Furnace.

When the ore of iron is collected. it is not in a state fit for use: the extraneous substances with

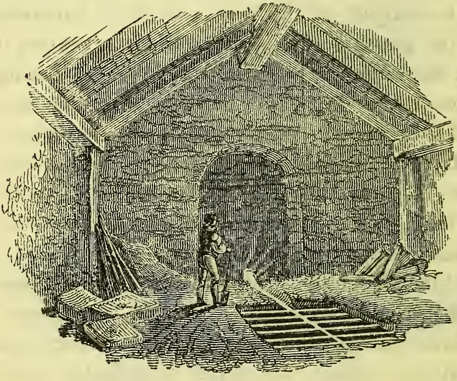
which it is connected must be removed, and this is done by smelting. The bottom of the furnace is first filled with fuel: the ore is then broken into small pieces and mixed with lime, to render it more capable of fusion; it is then thrown into the furnace, with a certain proportion of charcoal or coke.



Head of a Smelting Furnace.

When the fire is kindled, the combustion is aided by a pair of large bellows, and a most intense heat is quickly produced by the blast: the ore nearest to the fire is soon melted, and falls through the fuel to the bottom, where it is

collected; that which rests upon it sinks into its place, and is melted in the same manner. Fresh ore and fuel are then added, and the process continued till the melted metal, rising nearly to the height of the nozzle of the bellows, is let off into transverse moulds, sunk into the floor of the sand. The casts are called pigs, and are ready for the use of the founder.



Bottom of the Furnace. with the process of Pig-casting.

Cast-iron is converted into wrought-iron by a refining process called puddling. The cast-iron contains a large quantity of carbon, and other impurities, of which it must be divested to render

it thoroughly malleable. For this purpose the iron is melted in a furnace, and kept in a state of fusion for a considerable time, and repeatedly stirred. The carbon is thus made to combine with the oxygen of the atmosphere, forming carbonic acid, while a part of the oxide of iron, united with the earthy matter, rises to the surface as a slag. The melted mass of iron then begins to get thicker, and is removed from the fire. It is then subject to the beating of large hammers, or the pressure of rollers, by which a portion of the impurities are squeezed out. After passing through this process, it becomes malleable iron, and is brought into the market, either in bars or rods; but, during the progress of the manufacture, it loses weight from the oxidizing of the surface, scaling, and the diminution of the impurities.

"In purchasing wrought-iron, the workman distinguishes two kinds, which are both of very inferior value; they are called hot-short, and cold-short iron. The former is a fusible metal, which possesses ductility when cold, but is so brittle when heated, that it will not bear the stroke of the hammer: the cause of this variety is not known. The latter kind is very malleable and ductile while hot, but the utensils made with it are as brittle as cast-iron, when cold: such iron

contains a portion of phosphate of iron, which Bergman believed to be a new metal."

The process of making steel may now be noticed :—

When wrought-iron is slowly heated in contact with charcoal, it takes up a portion of carbon, and gives off oxygen, by which it is formed into steel. Cast-iron also contains carbon, but steel differs essentially from that substance in being divested of its oxygen and earthy matter. When only a small quantity of carbon is united with the iron, the metal does not lose its malleability: when a large quantity is given, it can no longer be welded, or incorporated. To determine which is iron and which is steel, of two pieces of metal, it is only necessary to drop a little nitric acid on each, and a black stain will be produced on the surface of the polished steel, but not on the iron. When steel is raised to a high temperature and suddenly cooled, it becomes exceedingly brittle, and, in fact, unfit for manufacture. It is, therefore, tempered by the workman, or, in other words, brought to the requisite degree of hardness, of which an experienced person may judge by the colour.

Cast-steel is made by fusing iron at an intense heat with carbonate of iron. This substance contains more carbon than common steel,

but its manufacture was a long time considered as a secret. The process, however, is now well understood, and there can be, in the present day, no reason for a monopoly, if any still exists.

Steel was supposed to be a carburet of iron, a compound of iron and carbon. But Mr. Dalton states, that pure steel may be dissolved in acids without any residuum, and is of opinion that it obtains its peculiar properties from a singular crystalization, and not from its chemical composition.

During the last few years, the consumption of iron has been greatly increased. It is almost impossible to estimate how much our domestic comforts depend on the manufacture of iron, or how much the commerce of this country is indebted to the facilities of obtaining the ore. The introduction of railways is a new source of consumption. The same works are going on in America, and many of the European states: some of these we are supplying with the requisite rails, and nearly all of them with machines. If, then, we view our home and foreign trade in this one article, we may form some estimate of the great abundance of the ores of iron in our own country, and also the facilities we possess of smelting it, from the abundance

of coal near to those spots where the iron is chiefly obtained.

Mr. Malkin gives the following account of Merthyr Tydvil, a town in South Wales, celebrated for its iron manufactories :—" It was a very inconsiderable village till the year 1755, when the late Mr. Bacon obtained a lease of the iron and coal mines of a district, at least eight miles long and four wide, for ninety-nine years; since that period, the mines have been leased to four distinct companies, and produce to the heirs of Mr. Bacon a clear annual income of ten thousand pounds. The part occupied by Mr. Crawshay contains now the largest set of iron works in the kingdom; he constantly employs more than two thousand workmen, and pays weekly for wages, coal, and other expenses of the works, twenty-five thousand pounds. The number of smelting furnaces, belonging to the different companies at Merthyr, is about sixteen: around each of these furnaces are erected forges and rolling-mills for converting pig into plate and bar iron. These works have conferred so much importance on the neighbourhood, that the obscure village of Merthyr Tydvil has become the largest town in Wales, and contains more than twelve thousand inhabitants."

Cast-iron and steel are more frequently used

for domestic purposes than that which is wrought: kettles, pans, saucepans, fenders, and other articles, are made of cast-iron.

The simplest method of casting is the following :—A model is first formed, and an impression is taken upon sand, contained in two open frames; when the mould is thus made, the two frames are put together, and the melted pig-iron is poured in through a channel left for that purpose.

When iron is exposed to a damp atmosphere, and especially when there is an alternate exposure to water and air, it slowly combines with oxygen, or, in other words, rusts. This effect is also produced by raising the temperature : when a bar of iron is kept for some time at a red heat, it is covered over with a coating of the oxide of iron, and when forged, thin plates are thrown off from the surface.

All those kitchen utensils used for boiling water, and other culinary purposes, are peculiarly exposed to oxidization, and there would, consequently, be a great deal of difficulty in keeping them clean, if there were not some method of preventing the effect altogether. This is done by a process called tinning; and where iron cannot be used, tin is employed : thus we have what are termed tin tea-kettles, tin saucepans, and other articles. But it must not be

supposed that these utensils are actually formed of tin; they consist of thin plates of iron, covered with a coating of tin, or, more properly, made to combine with a portion of tin. This is done in the following manner:—The iron plate is first thoroughly cleaned, being well rubbed with sand, and then steeped in very diluted muriatic acid: after being baked to remove the scales, the plates are hammered, and passed through rollers. When thus prepared, they are dipped into a chemical composition, called sours, and afterwards into melted tin, which unites with the iron. These tin plates are sold by the retail ironmongers, and converted into various instruments and utensils.

Copper vessels are sometimes used in cooking, and they are almost always tinned, for when they are not kept clean, a greenish blue crust is formed, which, if mixed with food, and taken into the stomach, becomes dangerous to life. Many instances of poisoning from this cause are recorded. It is not, however, generally known, that fat substances and vegetable acids do not attack copper while hot; if, therefore, the liquid be emptied from the vessel while hot, no danger can be incurred, but if it should remain in the vessel till cold, the carbonate of copper is then formed. To prevent all chance of danger, copper

vessels should always be tinned, and this is generally done; but, after being in use some time, the tin wears off, and the process should be repeated.

There is one other property which may be communicated to iron and steel, which must now be noticed. It was known at a very early period, that a certain ore of iron possessed the property of turning itself to the north and south poles of the earth: this is called its magnetic property: and so well are we acquainted with its principles of action, that the navigator feels no fear in trusting the safety of his vessel to its guidance. The magnetism of iron may be communicated from one substance to another in a variety of ways. If a magnet be placed in contact with a piece of iron, it communicates to the ferruginous body the same property; so if a bar of iron be rubbed with a magnet, it receives the magnetic principle. Pieces of iron used in the construction of buildings, and in a vertical position, are generally magnetic. When lightning passes through an iron bar it acquires the same property, and a poker is seldom altogether destitute of it. If the poker should be found, on experiment, to have no magnetism, it may be easily induced by holding it with the point downwards, and striking upon the head with a hammer several times.

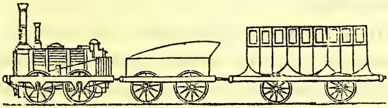
When the end of a piece of soft iron is brought near to an end of a magnet, it instantly becomes magnetic, and has all the properties of the loadstone; but, as soon as it is removed from contact, it loses its newly-acquired properties; and even if it were rubbed, the same result would follow. To form a permanent magnet, steel must be used. The needles used in compasses are formed of this material, and, when properly shaped and hardened, are touched; by which process they are formed into true and permanent magnets.

There are many uses to which iron is applied, of which we cannot speak. The cooper binds his casks with iron hoops; nearly all workmen's tools are formed of iron; and there is scarcely an art, from that which is most refined, to that which is most common, in which it is not of importance: and hence it is that the blacksmith will inform you, that, of all artizans, he is least dependent on other trades.

Gisborne says, with great truth:—" It is the possession of iron which constitutes, humanly speaking, the difference between savage life and civil society. Its value is instantly discerned even when the eye is but half opening, and the mind but half awakening from the night and torpor of barbarism. When a ship on a voyage of discovery touches at a new island, what among the

productions of an unknown hemisphere, laid before the wondering native, are speedily the objects of his most intense solicitude? A hatchet, an adze, a nail, or a piece of broken iron, of which he knows only that it is iron, and has not yet thought of a purpose to which it may be applied: but he knows that it is iron, and that is sufficient. In civilized life, the same metal which the Deity has mercifully provided in larger abundance than any, or than all the rest, maintains, under its varied states and capabilities, a decided pre-eminence in utility."

The application of iron in building, in the making of rail-roads, in the navigation of vessels, and in all our manufactures, will at once occur to the reader.



RAILROAD, WITH ENGINE AND CARRIAGE.

CHAPTER III.

GLASS.

FLINT—OTHER INGREDIENTS OF GLASS—BLOWPIPE—GLASS BLOWING—TELESCOPE.

In the manufacture of glass, to which we are so much indebted, flint, which is called silica by chemists, is a most important ingredient. It is one of the earths, of which there are ten, namely, silica, alumina, zirconia, thorina, glucina, yttria, barytes, strontian, lime, and magnesia. They are all incombustible bodies, and were, at one time, thought to be incapable of decomposition; but they are now known to be certain substances, chiefly metallic, combined with oxygen. It was supposed by some chemists, from a comparatively early period, that the earths were compound substances, and many attempts were made to discover the supposed metallic bases. It was, however, left to Sir Humphrey Davy to prove the truth of this supposition.

Davy was not able to produce a complete separation of silicium, the base of silica and oxygen, though the result of his experiment left no

doubt in his own mind, that this earth was composed of oxygen and a base. Berzelius, however, succeeded in effecting the decomposition, by fusing it with charcoal and iron. In this way he produced an alloy of silicium and iron. Pure silicium is an incombustible substance, and a non-conductor of electricity: it is not acted upon by any substance except fluoric acid, so far as we know at present. If dry carbonate of soda be added to silicium heated with nitre, a detonation is instantly produced.

Silica is a substance most abundantly distributed in nature: flint, sand, quartz, and gravel, are all siliceous, but not pure silica. They may, however, be reduced to an almost pure state by the following process. Take some small pieces of clear quartz, and calcine them at a low heat, and then reduce them to powder; mix the pulverized flint with three or four times its weight of carbonate of potassa, and fuse the compound; a process which will require great care, as the mixture will otherwise rise, and probably overflow the vessel. When the materials have been in perfect fusion for little more than half an hour, pour the compound of silica and alkali into an iron dish. It may afterwards be dissolved in water, and poured into diluted sulphuric or muriatic acid. A precipitation will be immediately

produced, and as long as this continues a fresh quantity of the solution may be added. The sediment must then be washed and dried, which process will put the experimenter into possession of a tolerably pure silica.

Let us now examine the use of this substance in the manufacture of glass. It is of great value in many works of art, such as the formation of earthenware and porcelain, but at present we must entirely confine our attention to the construction and use of glass.

When silica is mixed with an equal quantity of carbonate of potassa, and raised to a great heat in a furnace, it melts, and glass is formed. It appears from history, that the manufacture of glass was known at a comparatively early period. It was, however, an article of great value in the time of Nero, who gave a considerable sum for two drinking glasses; yet it appears to have been sufficiently common for use in windows, as several of the houses in the town of Pompeii, which was buried by an eruption of Vesuvius, A.D. 79, were glazed with a thick, semi-transparent glass.

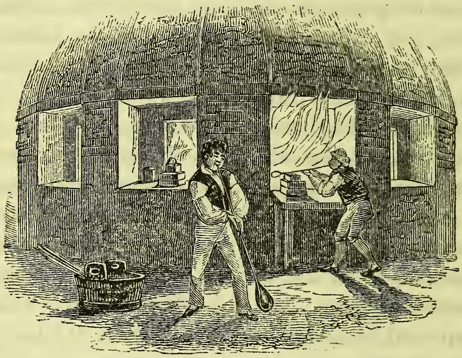
Many other ingredients, besides silica and an alkali, are frequently used in the manufacture of glass. Flint glass is composed of silica, litharge, nitre, and manganese; crown glass of silica,

soda, and lime; plate glass of silica, soda, lime, manganese, and oxide of cobalt; green bottle glass of silica, kelp, pearlash, and clay; artificial gems or pastes are made of pure silica, borax, nitre, and oxide of lead, other substances being added as required, to produce the colour of which an imitation is to be formed.

In the manufacture of glass a great heat is required, for the alkali, which must be used, can only be melted at a high temperature, when it enters into composition with the earthy substance. It was once supposed that a very strong chemical attraction existed between the constituent substances; but this supposition has been disproved by many recent experiments. "Glass," says Dr. Faraday, "may be considered rather as a solution of different substances one in another, than as a strong chemical compound; and it owes its power of resisting chemical agents generally, to its perfectly compact state, and the existence of an insoluble and unchangeable film of silica, or highly silicated matter upon its surface." Glass is sometimes *cast* into the forms required, but is more frequently *blown*.

If any of our readers should wish to have a practical acquaintance with chemistry, we would seek permission to give a little advice. Never depend on

the skill and attention of others: be independent. If this recommendation be followed, it will save



Glass Furnace, and Glass Blowing.

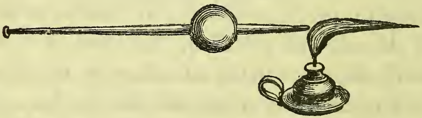
much money, much trouble, and, above all, much time. A man who wants workmen always in attendance at his laboratory table, can never be a practical chemist. There are instances in which he will require assistance, but he must learn to do as much as possible for himself, otherwise he will never succeed in performing his experiments at the time, or in the manner, he wishes. Now, of all operations required by the chemist, no one is more important than that of preparing his own glass vessels; and although the task may, at

first, appear difficult, it will soon become easy by practice.

There was a time when all chemical experiments were made on so large a scale, that it was impossible for any person to study the science without expending a great deal of money, and devoting all his time to the subject. But, in the present day, the student may manufacture nearly all his glass vessels with a common blowpipe, which he may also construct. First, obtain, or make, a common pair of bellows, which may be worked with the foot. To the nozzle of the bellows, attach a tube in a vertical position, and let it come through or by the side of the deal table on which the experiments are to be performed: to the end of this vertical tube a small jet must be attached, and fixed in such a manner, that a current of air may be blown through it, so as to direct the flame of a spirit lamp on any object, the temperature of which is to be raised. If this, however, cannot be obtained, a small blowpipe, similar to that used by goldsmiths, and supplied with air from the lungs may be used. At first, the experimenter will not be able to obtain a steady flame by this means, but he will succeed after a little practice. Having obtained his blowpipe, the student must provide himself with some glass tubes, which

are bought by the pound : the size of the tubes must be chosen according to the purposes for which they are required.

Being thus supplied with materials and instruments for manufacture, the student may commence his operations. Suppose, for instance, that he requires a test tube, upon which to make some experiments upon the affinity of substances. A piece of tube must be cut off to the length required, between three and four inches; and as both ends are open, one is to be closed. The flame of a spirit lamp is now directed upon the end which is to be sealed up, by the stream of air proceeding from the blowpipe. In a very



Blowpipe.

short time, the glass is raised to a high tempera ture, and becomes soft, and may be sealed up little by little, and when it appears to be quite closed, heat it again until it is almost liquid, and then placing the opposite end to the mouth, blow into the tube, which will force the melted glass into a globular form, and make a very neat end. A thermometer bulb may be blown in the same

manner. In performing this operation, it will be necessary to continue blowing into the tube, heating it again each time until the bulb is of the size required, and taking care not to inhale the heated air from the tube.

When it is necessary to seal the ends of small tubes, it is better to take a piece longer than is required, and heat it at the point where it is to be sealed. The glass, when brought to nearly the point of fusion, may be suddenly drawn out, and a very fine hair-like thread will be formed. At that part nearest to the end, the thread may be broken, and will be at once closed by melting the glass at that point into a small globule, after which it may be acted upon as required, and perfectly formed. A lip may be made to this newly formed vessel without any trouble; the glass will be heated in the same manner as before, and when quite soft is pressed into the form required, by a piece of wire, or the end of a file.

These hints may be of service to the young chemist, who will, after a little while, become expert in forming vessels of any shape he may require. The process is simple, and may be practised by any person: a little manual skill is all that is necessary. This description may also assist our readers generally in understanding the means by which glass is blown in factories, the

only difference being, that in large works the glass is melted in intensely hot fires instead of the flame of a spirit lamp.

Glass derives nearly all its importance from the possession of the property of transparency. It is true, that if it were an opaque substance it would still be of great value, as it may be put into shapes which are required for ordinary domestic purposes. Still its chief value depends on its capability of transmitting the rays of light. As this is its principal use, it will not be an inappropriate conclusion to this paper to illustrate its effects upon solar light.

Light moves in right lines when uninfluenced by an impeding medium, but when any transparent substance interferes, its direction is turned, it is bent out of its course, or, in other words, is refracted. Before a ray of solar light can reach the earth, it must pass through the atmosphere, and, during its passage, it is refracted. Now, the same ray may have to pass through a pane of glass, and in doing so is refracted again, because it enters a medium of different character, so that the ray of light, proceeding in a right line from the sun, is twice turned out of its course before it reaches the eye of the observer, situated in any apartment receiving light through glass. The effect of water in refracting, or bending

the rays of light, can scarcely have been unobserved by any person who has been at all attentive to the objects surrounding him. If a stick be plunged into a stream of water, it will appear as though broken at the surface, for immediately the ray enters the new medium it receives another direction. So light, passing from the atmosphere into glass, suffers the same change. Should, however, the ray be perpendicular to the surface, it will pass through without refraction.

As glass is one of the most transparent mediums with which we are acquainted, and may be easily converted into any shape required, by grinding, it is commonly used in the construction of optical instruments. Some microscopes and telescopes are entirely formed of glass, that is, all but the exterior case; and the principle of their construction is readily understood by those who know the effect of differently formed lenses upon a ray of light. Glasses of some shape cause an object to appear larger than it is in fact; others make it smaller: some cause the rays to diverge, others converge them. The object of the optician, therefore, is so to place his lenses that they may effect the required object.

The principle of reflection is sometimes called into operation in the manufacture of optical

instruments. The looking glass is the most simple of all reflecting instruments; it consists of a piece of plate glass, the surface of which is covered with a metallic substance, incapable of transmitting the rays of light. When a solar beam impinges, or falls, on this medium, it is returned in a line which forms the same angle with a line perpendicular to the surface, as the incident ray, but on the opposite side of the perpendicular. It is evident that a reflector may be made of any form by covering the anterior surface of glass with a metallic compound, but such mirrors are far less used than those composed of metals. In the construction of optical instruments, metallic mirrors are almost exclusively used where reflection is required. The chief use of glass, therefore, in a scientific point of view, depends on its transparency, and its powers of refraction. If it were not transparent, it would be of no use to the chemist in his operations, for he could not observe the processes which are carried on; and it would be of no use to the astronomer or naturalist in the construction of telescopes and microscopes, if it did not possess the power of refraction. The common purposes to which glass is applied are so well known, that it is altogether unnecessary to specify them.

To mention only one instance, how largely has

the telescope contributed to our knowledge of the starry heavens! Instead of now supposing that our earth, with its planetary system, is the chief occupant of space, we are conducted to the conclusion, that if it were all annihilated, the loss to the material universe would be no more than that of a few leaves from a forest, or a few grains of sand from the sea-shore. Astounding is the thought; we ask for some means of conceiving of the relative proportions and distances of the bodies connected with our system, and an eminent philosopher, Mr. Whewell, has thus acceded to our wishes. "If," says he, "we suppose the earth to be represented by a globe, a foot in diameter, the distance of the sun from the earth will be about two miles; the diameter of the sun, on the same supposition, will be something above a hundred feet; and, consequently, his bulk such as might be made up of two hemispheres, each about the size of the dome of St. Paul's. The moon will be about thirty feet from us, and her diameter three inches: about that of a cricket ball. Thus, the sun would much more than occupy all the space within the moon's orbit. On the same scale, Jupiter would be above ten miles from the sun, and Uranus forty. We see, then, how thinly scattered through space are the heavenly bodies. The fixed stars would be at

an unknown distance; but, probably, if all distances were thus diminished, no star would be nearer to such a one-foot earth than the moon now is to us.

"On such a terrestrial globe the highest mountains would be about 1-80th of an inch high, and, consequently, only just distinguishable. We may imagine, therefore, how imperceptible would be the largest animals. The whole organized covering of such an earth would be quite undiscoverable by the eye, except put up by colour, like the bloom on a plum.

"In order to restore the earth and its inhabitants to their true dimensions, we must magnify the length, breadth, and thickness of every part of our supposed models forty millions of times; and, to preserve the proportions, one must increase equally the distances of the sun and of the stars from us. They seem thus to pass off into infinity; yet each of them thus removed, has its system of mechanical and, perhaps, of organic processes going on upon its surface."

Such views are eminently calculated to impress us with a sense of the greatness and glory of our adorable Creator, by whom our system was at first called into existence, and by whom it is still maintained and governed. Yet what is our system to the universe? It appears that every one

of the little lights arraying the blue vault of heaven, with the exception of a few, is a sun like our own, and has probably a planetary system analogous to ours. Let us then listen to the voice that says:—"To whom then will ye liken me, or shall I be equal? saith the Holy One. Lift up your eyes on high, and behold who hath created these things, that bringeth out their host by number: he calleth them all by names by the greatness of his might, for that he is strong in power; not one faileth. Why sayest thou, O Jacob, and speakest, O Israel, My way is hid from the Lord, and my judgment is passed over from my God? Hast thou not known? hast thou not heard, that the everlasting God, the Lord, the Creator of the ends of the earth, fainteth not, neither is weary? there is no searching of his understanding," Isa. xl. 25—28.

Almighty God, thy power we sing,
And to thy goodness tribute bring
For all thy works of love;
Thy wisdom crowns thy boundless might,
And kindness brings thy truth to light,
As clear as orbs above.

The universe thy greatness shows,
And endless space thy presence knows,
O wondrous, glorious God!
Thy finger marks the comet's sphere,
And countless orbs in full career
Pursue their various road.

Nor less the wonders of thine hand,
Which, nearer view'd, our souls command,
For grandeur shines in all;
The lightning's glare, the foaming deep,
The whirlwind's blast, the craggy steep,
Our trembling frames appal.

And wandering through this globe of earth,
On which unnumber'd tribes have birth,
In quick succession round,
We stop to gaze, but soon are lost
On seas of power creative toss'd—
The power without a bound.

How full the earth, and sea, and air!
How great thy love! what constant care
Of all the host is shown!
On great and small thy bounty flows,
And all creation richly glows
With goodness all thine own.

CHAPTER IV.

COAL.

ORIGIN OF COAL—IMMENSE DEPOSITS—MINING—COAL USED AS FUEL.

Entering on the interesting subject now announced, the writer disclaims altogether any pretence to communicate new or original discoveries and observations, or even to found on the information he has gleaned from various authors, any theories more consistent with ascertained facts, than those advanced by the eminent men who are at the present period bestowing on the science of geology the most patient, scientific, and enlightened research. All that he can hope to accomplish is, to place in a point of view, adapted to interest and entertain his readers, such knowledge of the subject as he possesses: and he is conscious how greatly he will need their candour, while pursuing even this more humble aim.

It may contribute to the more clear understanding of each successive point of the discussion, if, at the outset, the general plan and order now adopted is explained. It is, then, the intention of the writer, in the first place, to offer a

statement of the vast extent and quantity of this most valuable mineral deposit, and its immense importance to mankind ; then to describe its nature and qualities, and to adduce the facts which almost demonstrate its vegetable origin : in the next place to explain the circumstances under which it is supposed these immense strata of now mineralized vegetable masses were produced and deposited ; this will lead to an explanation of the present geological position of these vast mines stored up for the comfort and wealth of mankind ; and we may then finally explain the labour and skill now so extensively and successfully employed to disinter these buried treasures for the use and welfare of society.

As to the immense and extensive deposits of coal among the strata of our planet, at a depth and under circumstances accessible to the efforts and skill of man, and possessing properties so available for all the purposes of domestic economy, and of the productive arts, the thoughtful mind is by this circumstance forcibly referred to the ends proposed to himself by the almighty, all-wise, and beneficent Creator. We see a use, a value, an adaptation in things for specific purposes, which never could be fortuitous and undesigned. We must see, unless our minds are utterly blinded and perverted, that this world,

our abode, has been planned and gradually prepared for our habitation; that it is stored and filled with whatever, by supplying our wants, ministering to our comforts, enlarging our knowledge, and awakening our delight, can lead us to glorify our Maker, under the deepest impressions of gratitude and wonder for the varied and amazing displays of his goodness and wisdom, power and forethought, with which we are on every hand surrounded.

To select one instance, our own favoured island is very rich in coal. The northern mines, which supply the metropolis, and generally the southern parts of England, are wrought in strata which extend over eight hundred square miles, with an average thickness, in the best portions, of thirteen feet of excellent and workable coal. The west riding of Yorkshire, Lancashire, and Staffordshire, contain vast deposits of coal. But our richest store is in South Wales, where there is a coal deposit extending over twelve hundred square miles, and stated to be of the vast average thickness of ninety-five feet of workable coal, but not indeed of equal quality with that obtained from Durham and Northumberland. In the north of France there is a bed of coal extending in length one hundred and fifty miles, with a medium breadth of six miles. Various other parts

of Europe possess beds of coal. It is found in India and New Holland. North America possesses it to a vast extent. On the western slope of the Alleghanies there is a coal field which would cover the half of Europe. Our own colonies of Nova Scotia, Cape Breton, New Brunswick, and Australia, possesses coal in abundance. There are no richer coal fields in the world than are to be found in China and Japan.

Our knowledge of the surface of our globe is as yet in its infancy. As the wants or enterprise of man lead him to explore in every zone the wonderful scene of his abode, and as the light of science shall enable him to conduct his search with skill and success, supplies and resources of every kind will be discovered beyond all present knowledge or hope. And as knowledge and experience advance, it is not to be doubted, but that improved methods of mining coal, so as to obtain what with present means is inaccessible, will be invented; and that modes of consuming the produce of our mines, both more skilful and more economical, will be adopted; as, also, that methods of transporting a commodity of such great bulk and weight as coal, from districts where it is produced to those destitute of the treasure, far more effectual and cheap than those now in use, will be discovered. For when we

consider the extent to which, in our own island especially, the consumption of coal is now carried, and the interests, not to mention the comforts, of the whole population dependent upon its continual supply—when we reflect how the use of it is daily extending in the application of steam to the arts and manufactures, and to the purposes of locomotion both by land and water—when we observe, in fact, that the greatness, wealth, intelligence, household comfort, and, in short, the whole structure of society of Great Britain, rest at this moment to such a degree on the use of the steam-engine, which our coal alone enables us to employ, it might even now be a question of anxiety for the future, Will not our coal mines be exhausted at some not very remote period? and when they are worn out, what will become of Britain?

Now, to relieve solicitude for the future on this account, it is, in the first place, certain, that the coal fields of our country contain supplies sufficient for many centuries. Those who adopt the lowest calculation of the quantity contained in the northern beds, suppose it would last, at the present rate of consumption, and with the present mode of mining, which is wasteful, and by no means extracts all the coal of the seams that are worked, four hundred years. And

Mr. Bakewell calculates, that the immense mass in the South Wales formation, already alluded to, would supply England with fuel for two thousand years after all our English mines shall be worked out. If it be replied, that the rate of consumption will, probably, greatly increase, it may be rejoined, that much more economical modes will hereafter be adopted in the use of fuel, both for domestic purposes, and for steam-engines and smelting furnaces. Already one bushel of coal is made to produce a force of steam, which forty years ago required sixteen bushels : therefore, had the same extent of steam power been required that is now employed, with no improvement in the art, and no economy in the fuel used, the steam operations of England would now be actually consuming sixteen times the coal they do in fact burn out.

We may indulge better anticipations concerning the future destinies of man, both in our own island and throughout the world, in respect of all the supplies and comforts of life, when we reflect on the wonderful resources art is continually discovering in nature. What surprising facts are known to us, of the nature and use of various substances, concerning which early ages were entirely ignorant ; and long before that far remote period when our coal mines, and those of other

nations, are exhausted, new substances capable of supporting combustion, and supplying heat, when employed for that purpose in ways now unthought of by us, may have been discovered. And as when the forests on the surface of our soil ceased to afford a supply of fuel, the art of mining and burning coal came in to present a substitute; so when coal in its turn shall fail, (if it should,) the chemists of that remote age may possibly teach men to burn the carboniferous limestone of their mountains and hills.

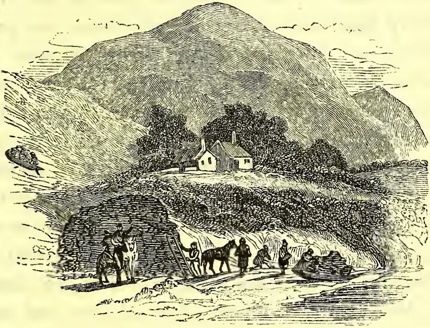
But as, on one hand, nothing can afford a greater evidence of Divine foresight and design than the storing in the earth these almost endless supplies of fuel; so, on the other, nothing can more clearly demonstrate that for man this world was made and furnished, than his endowment with faculties for invention, experiment, and discovery, to make the utmost use of the various materials with which he is furnished, as is seen in the almost endless purposes to which the steam generated by burning coal is employed. We find the swiftest travelling, the most perfect and delicate manufactures, the most rapid and extensive spread of knowledge, and interchange of thought and intelligence, all equally attained by the application of steam. And the thought becomes sublime indeed, if we believe it was in the

foresight of these results, and in the express intention to accomplish them, that, in previous states of our planet, wide forests were made to vegetate and decay, to supply, in their carbonized remains, the chief instrument of British commerce, wealth, intelligence, and power, after so many generations of men should have lived and died.

The coal we use, to speak now of its nature and vegetable origin, is a compound of carbon, bitumen, and earthy matter, in varying proportions. Anthracite, or stone coal, is destitute of bitumen. Lignite, or wood coal, is not perfectly mineralized. Coal in which there is but little earthy mixture, and which contains a due proportion of bitumen, is the most valuable: it cakes in burning, and leaves but a small residuum of ashes, which always consist of the earth contained in the coal. Our pit coal is a pure mineral: it has the mineral substance, grain, and fracture; and, from inspection of the material itself, it would be thought to have an origin, not in any respect differing from that of other stony substances quarried out of the strata of the earth. More accurate inquiry and examination will, however, soon change this opinion, and conduct to the conclusion now generally received, that coal is of vegetable origin. The facts and considerations on which this opinion

rests are various. In the first place, we have in peat and lignite, examples of a process similar to that by which coal is supposed to have been formed, and of the change of vegetable matter into coal at different stages of its progress.

Peat consists of vegetable matter, bitumenized by fermentation in places where it can be kept saturated with moisture, and where both the access of external air, and the escape of the most volatile parts of the mass are effectually prevented. As the workmen penetrate deeper into the mass of peat, the portions thev raise are



Peat-cutting near Cader Idris, North Wales.

more completely bitumenized, and the fluid or sludge, at which they ultimately arrive, is in the

highest degree bitumenous, and after being dried in shallow reservoirs, the solid mass that remains is found to burn most easily, and with the greatest fierceness. But in peat, though vegetable substance is bitumenized, it is not at all mineralized, because it has never been subjected to pressure, but is rather a spongy mass, somewhat more solid indeed in the lower portions than in those nearer the surface.

Again, in what is called lignite, or wood coal, or suturbrand, we have another form of vegetable substance become bitumenous, and in different degrees mineral also, without having lost the woody fibre, texture, and form, in which it originally grew. There is an extensive deposit of this substance at Bovey Tracey, in Devonshire, whence it has received, in this country, the name of Bovey coal. Here is found a much more recent deposit than the proper mineral coal seams ; it is thought, indeed, to be more recent than even the chalk. It consists, besides, of certain trees, which grow to greater mass and solidity, and in which the woody fibre is far more firm and lasting than the other plants of which the true coal is supposed to be composed. Here, then, is a substance, found in strata alternately with beds of clay, which is at once wood and coal. There is the grain, fibre, and form of wood, but it is

bitumenous in a high degree, and different portions of it are in different degrees mineralized. Some are soft, and will bend as a piece of board; others are brittle, and have the weight, substance, and fracture of a mineral. As, therefore, we have vegetable matter thus accessible in its progress to bitumenization and mineralization, the two great characteristics of coal, a presumption arises, that coal itself has arrived at its most complete attainment of these properties from the same origin, by a more lengthened and complete subjection to the same process.

Pecopteris heterophylla, from a specimen taken from the High Main Coal Seam, in Felling Colliery, Northumberland.

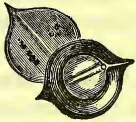
A second consideration which exceedingly

confirms the probability arising out of the former, that coal is of vegetable origin, is, that traces of vegetable remains are most abundant in immediate connexion with seams of the most perfect coal. In perfect coal itself they, of course, are not found, because, when the process of forming coal is complete, nothing can be discerned but a uniform mineral mass of carbon and bitumen. But coal is universally deposited in seams of no very great thickness, alternating with beds of indurated clay, shale, and similar substances. Now, in these are found the stems, the leaves,

Cardiocarpon acutum, from a specimen in shale, taken from the Bensham Coal Seam, in Jarrow Colliery, Durham.

the fragments of plants; and these in such

positions, and sometimes so partially converted into coal, as to leave no room to doubt that the entire mass of coal is composed of vast quantities of similar plants, of which these poor remnants alone escaped, to bear witness to the existence and fate of those luxuriant forests in which they once flourished.



Seeds of the *Cardiocarpon acutum.* The natural sizes.

Another striking proof this kind will avail more than lengthened general descriptions. When a seam of coal is mined, the surface of shale, or other substance, on which it rested, is called the floor, and the under surface of the stratum of shale, which rested on it, is denominated the roof. Now, it will in some instances occur, when the coal is removed, that the roof will exhibit, traced on it with most beautiful and delicate accuracy, the leaves, the stems, the forms of various plants; the substance of the clayey stratum often forming a light ground on which the plants are traced in shining black. Now, this appearance reveals the history of the coal formation. A mass of vegetation, either by growth or transport, occupied the space now filled with perfect coal, while that mass, or at least the upper surface of it, retained uninjured its vegetable form and structure: the

mass, now forming the stratum resting upon it, was deposited, most probably, by gentle, gradual deposition from turbid waters, and received on its under surface the tracing of every line and fibre of the plants on which it pressed. These afterwards fermented, blackened, and hardened into coal; and by colouring the traced impression on the incumbent stratum, made visible what otherwise might have remained the imperceptible mosaic of the roof under which the miner plies his laborious and hazardous task.

Coal is now indeed universally allowed, by geologists and chemists, to be a vegetable substance. It is found in beds, varying in thickness, in many parts of England and Wales. A clay ironstone, from which a large portion of the iron used in this country is obtained, is usually associated with it—a circumstance of great importance, because the presence of coal upon the spot greatly facilitates the process of smelting. It is often observable, that strata of ironstone, coal, and lime, are found to be alternate: so that on the same spot may be obtained the ore of the metal, and the fuel and the flame to fuse it.

"Few persons are aware," says Dr. Buckland, "of the remote and wonderful events in the economy of our planet, and of the complicated applications of human industry and science, which

are involved in the production of the coal that supplies with fuel the metropolis of England. The most early stage to which we can carry back its origin, was among the swamps and forests of the primeval earth, where it flourished in the form of gigantic trees. From their native bed these were torn away by the storms and inundations of a hot and humid climate, and transported into some adjacent lake, or estuary, or sea. Here they floated on the waters until they sank saturated to the bottom, and, being buried in the detritus of adjacent lands, became transferred to a new estate among the members of the mineral kingdom. A long interment followed, during which a course of chemical changes, and new combinations of their vegetable elements, have converted them to the mineral condition of coal. By the elevating force of subterranean fires, these beds of coal have been uplifted from beneath the waters to a new position in the hills and mountains, where they are accessible to the industry of man."

This information is not only deduced from the composition of coal, but from the situations in which the beds are found. The vegetable matter of which it is formed must have been deposited in a horizontal position; but, by the agency of some most violent causes the beds have been

upheaved, and, instead of being buried at a considerable depth under a long series of rocks, it is found on the surface. In all these phenomena we trace the hand of a wise and benevolent Creator, who so directed the influence of his physical agents, as to secure the comfort and happiness of his intelligent creature man.

If we now proceed to some explanation of the circumstances under which these vegetable masses are supposed to have been deposited, and then converted into coal, we shall, in our progress, find opportunity to obviate the two great difficulties with which the doctrine of the vegetable origin of coal is encumbered. One is, the vast quantities of this mineral, which it is difficult to conceive could ever have been supplied by vegetation, the more especially when the great compression to which vegetable substances must have been subjected to reduce them into the dense, compact form of coal be considered. And the second, the entire, perfect change plants must have undergone before they could be converted into the compact substance of mineral coal. Nothing of the plant seems, to the senses, left. The plant is gone, a stone occupies its place, and we are required to believe that what is now the stone was once the plant. Wonderful operations must no doubt have attended both the

production of the vegetable origin of coal, and its conversion into that substance. Here we are transported into far remote geological eras, and have to contemplate the primeval state of our planet by such glimmering lights as reveal to us its then condition, and the operations of which it was then the scene.

The coal formations are the most recent of the transition rocks, and complete that series of geological formations. Let it be considered that the primary, granitic rocks form the substratum of the earth's crust, as far as known to us. What may lie beneath them is to us unknown, and matter of mere conjecture. This primary group consists of unstratified, crystalline rocks, the granites, gneiss, and mica slates. In them, or associated with them, are found no organic remains whatever, vegetable or animal, nor any traces of the existence of organized forms during the period of the deposition of these rocks, or while they alone continued to form the crust or surface of the globe. By some potent, irresistible forces acting from beneath, these solid masses were disrupted, fractured, and made to present an uneven surface of alternate elevation and depression. Upon them were then deposited what geologists term the transition series, consisting chiefly of the old red sandstone, various slates,

and the old carboniferous limestone. It is in connexion with this series of rocks that the earliest traces of organized existence in our planet are found; but these remains are of the most simple and the lowest orders, both of animal and vegetable life. It was while these transition formations constituted the surface of the crust of the earth, that the vast accumulations of vegetable substance now converted into coal were produced and deposited.

Now, it may be thought the mere play of fancy to attempt a description of the primeval globe in a period so remote, of which we seem equally destitute of record or means of information. Yet this is not altogether the case. Indications of the then state of the world have been traced, by able and sagacious observers, in the facts connected with that period, which remain to this day accessible to observation and research. In the basin or trough-shaped hollows, in which it is evident that coal was originally deposited, evidence is found that our globe had, at that early period, been subjected to the disturbing forces which produced mountains and valleys, with their accompanying streams, marshes, and estuaries. In the tribes of plants, of which remains are obtained from the coal formations, proof is obtained of the general prevalence of a hot and humid

climate over the whole globe : because in every latitude where coal is found, the associated plants are such as now flourish only in tropical regions. From the amazing quantity of vegetable matter thus produced, and the great proportion of carbon contained in the coal into which it has been changed, it is inferred that the atmosphere was then highly charged with carbonic gas, which being abstracted by the rapid growth of immense tracts of vegetation, the air became gradually more fitted for the respiration of land animals. The alternating beds of shale and clay, universally occurring with the strata of coal, seem also to prove that our planet was then liable to tremendous periodical rains and inundations, as could not indeed be otherwise when a high temperature and a wide watery surface prevailed together; and that vast floods of water flowed from the elevated portions of the globe charged with earthy matter, which was deposited in the lower regions where the waters spread, and their course became less rapid and tumultuous.

These conditions being supposed, as of their correctness and reality there is, to say the least, a very high probability, it needs no great exercise of the imaginative faculty to picture to ourselves the scene amidst which our beds of coal had their vegetable origin. In the low, marshy

tracts of the ancient globe, there flourished wide fields of tropical sedge, reeds, canes, gigantic ferns, equisetæ, and other plants of a simple structure, such as require for their production great heat and moisture. Finding all the conditions necessary for their rapid and luxuriant growth, a high temperature, abundant moisture, and a plentiful supply of carbon from the atmosphere, they attained a luxuriance and magnitude, which even the present productions of tropical regions will not equal, though they may assist our conceptions. While these wide tracts of marsh vegetation were flourishing in rampant growth, torrents of rain fell in high and remote districts and washing away with them, by the violence of their fall and motion, the soil of extensive regions, the turbid flood rolled on towards the ocean. By the time it reached the wide hollows of the coal basins, it spread, and its turbulence and rapidity diminished. The reedy, sedgy vegetation, not rooted up and swept away, was swayed down and flattened by the mass of waters passing, probably slowly, over it, and loading, pressing it down by the mud plentifully deposited on the mass. The buried plants became the material of a seam of coal; the incumbent mud of a bed of clay or shale. The process would be often repeated. The clay

became the soil for a fresh growth of plants, to be again in its turn submerged, and covered with soil for the production of another harvest of vegetation. In all coal formations these conditions are observed. They are all formed in hollows; they all consist of numerous alternating beds of coal, and slate, or clay, of varied thickness, from the fraction of an inch to several feet.

It is not pretended that this description of the mode of the deposition of beds of coal will accord with every fact and appearance observed in these wonderful formations. There must have been many causes to produce, in different localities, variations of what might be, nevertheless, general operations and results. The purpose of the writer has been attained, if what has been advanced has proved sufficient to give an idea, probably correct, of the general circumstances and mode under which coal beds had their vegetable origin. The vast masses of vegetation thus buried, were saturated with water, and highly charged with carbon. It is also supposed that from some source they were impregnated with sulphuric acid, which would greatly promote their becoming bitumenized. It is probable, also, that considerable heat was present, partly evolved from the covered and decaying plants themselves; partly from the crust of the globe, which

at that period had probably a higher temperature than now; and partly from the greater warmth of the atmosphere and climate. Thus buried, saturated, and heated, the mass fermented and became bitumenous. Mechanical pressure constantly increasing, compressed the substance into the hardened, mineral state in which we find it. The causes now adduced, seem adequate to account both for the immense quantities of vegetation needed to form the coal strata, and also for the perfect transmutation of the vegetable into the mineral substance.

In regard to quantity and mass of plants, let it be remembered, coal fields, or basins, are found covering six, eight, or twelve hundred square miles. Of course, the marshy forest, or jungle, whose buried vegetation now forms the coal, was co-extensive with the present bed of coal. But from what is now witnessed, in many parts of the world, of extensive tracts of marsh or forest, we may conceive without surprise, in the primeval, uninhabited state of the globe, to which our present inquiries have reference, of marshy jungles one hundred and fifty miles in length, and six in breadth. And in respect to the thickness of the separate seams of coal, in some instances, as it would seem, reaching to several feet, the dense and lofty mass of luxuriant plants, produced by

the concurrence of every cause that could stimulate and force their growth, might be quite adequate for their production.

The change, indeed, in substance is complete and surprising. But here we are under some illusion from our senses, which can discern no resemblance or analogy between the materials forming a plant, and those constituting coal. The researches of the chemist teach us, that the ultimate particles of bodies the most diverse in sensible appearance and properties, are often identical in nature, though varied in proportion and combination. The same material may exist in a gas, or as a rock. Now, coal consists of carbon and bitumen, which is itself a compound of carbon and hydrogen. Coal, then, is chiefly composed of carbon and hydrogen : so also are plants. It is not, then, that the ultimate particles and elements which compose coal and plants are widely different ; for they are nearly identical ; it is only that the two substances are in form and sensible qualities quite diverse. In plants, carbon and hydrogen are connected with organization, life, graceful forms, sweet odours, and beautiful colours. In coal, carbon and hydrogen are seen in mass, inert, mineral, condensed. But they are the same ultimate matters still. And what is our world, in all its wonders and beauties,

but an incessant, varied, infinite series of changes and transformations, in which a few simple and ultimate elements are made to pass out of one combination and form into another, in a manner which we cannot trace without wonder and admiration, which at once delight and overwhelm our faculties?

It is true, that the most able chemists have endeavoured without success to form by synthesis, coal from vegetable substances. But though not completely successful, they have nearly approximated to the desired result. And we can by no means infer from their partial failure, that what they could not accomplish by art, has never been effected by nature. From the plants on which they experimented, proper bitumen could not be extracted. The aid of sulphuric acid was required. But that agent might be, and indeed most probably was, employed in the bitumenization of vegetable substances in the formation of coal. For coal when burned gives out a sulphureous odour; and in connexion with the coal strata, mineral springs, whose waters are impregnated with sulphur, frequently occur.

Nor is it consistent with sound philosophy, or the true interests of science, to abandon what there are strong grounds for believing to be

true, because the evidence is not perfectly complete, or because some difficulties remain which cannot be entirely removed. The reasons for believing that coal is of vegetable origin are very strong and conclusive: much more so than could have been reasonably expected in reference to a fact connected with the operations of nature in a period so remote, and in a state of the globe so different from the present. Instead of feeling surprise that there should still remain some obscurity, and some conditions that cannot be ascertained, in respect to this interesting but difficult inquiry, the just ground of astonishment is, that by patient observation and research so much light and evidence relative to it should have been obtained.

There are, however, two conditions of this vast and wonderful natural process, which the chemist in his laboratory can never command, but which must yet materially affect the nature and success of the result: these are quantity and time. It is a familiar fact, that a great body of fermenting liquor attains a quality which cannot be realized in smaller quantities, and that there are processes which cannot be hurried to their result. Now, in the coal formations, both these circumstances concur to the utmost. The quantities of submerged plants were immense;

the exclusion of atmospheric influence complete; the time of their subjection to chemical action, and mechanical pressure, indefinite ages; the pressure acting on them incalculable, as successive strata were piled over them to the height of many thousand feet. These are circumstances which admit of no imitation or substitute; and the result of operations so conducted may naturally enough attain a perfection not imitable by the utmost skill in chemical processes. Besides, it is impossible to determine that there were, when the plants now forming our coal strata flourished, no conditions of the atmosphere, or of water, or of vegetation, as influenced by these, unknown at present. The water might, be acidulous, the air might be impregnated with gases now exhausted, which together would impart qualities to vegetable productions, that might without rendering them materially different from their present types, yet render their transmutation intò bitumenous, mineral coal, more certain and complete than our present plants could be made to undergo.

The present geological position of these strata of coal, so long ago deposited and converted, is a portion of our subject full of interest. It has already been stated, that the coal strata rest on and complete the series of formations, termed by

geologists the transition rocks; these resting on the primary, granitic masses. Since, therefore, the deposition of the coal, there have been added to the crust of our globe all the secondary and tertiary series: the sand stones, the calcareous rocks, and the chalk of the secondary formations; the fresh-water and marine formations, the clays, the diluvium and alluvium of the tertiary series. If, therefore, the coal had remained undisturbed where it was first produced, and, had that been possible, the various strata subsequently deposited had remained also undisturbed in regular succession one over another, these beds of coal would have been buried at the depth of many thousand feet beneath the surface, their treasures useless, and their existence unknown.

Nothing is more plain than that those convulsions of nature, which the condition of the surface of the earth every where proves it to have undergone, were essential to render it a habitable abode for man, though they may present to his imagination only images of violence, destruction, and terror. But for the effects of those amazing forces which have fractured the solid surface of the globe, and upheaved some portions, depressing others, there could have been no bed for the waters of the ocean, no solid continents, rising above the level of the waters, secure from their encroachments; mountains and hills, valleys,

slopes, and plains could have no existence. There could have been no springs, or streams of water; no vegetable soil, or varied scenery. Indeed, imagination itself can form no idea of our world, as consisting of an outward crust composed of successive coats of solid rock, arranged one within another, in unbroken continuity over the whole extent of the sphere, but as a production of simple creative power, and destined to purposes altogether different from those for which this world was created, and has been prepared.

Deep in the heart of the globe, we know not how far beneath the lowest strata with which we are acquainted, is the great laboratory where the forces and materials of nature are prepared for modifying the surface of the planet, by mighty convulsions indeed, but with most beneficial results. Every thing indicates that fire is a principal agent in producing these mighty forces. By their struggling and heaving from beneath, the solid crust of the earth, notwithstanding its enormous thickness and mass, has been fractured, and portions even of the lowest rocks have been forced upward, so as to form the lofty ridges of the highest mountains in the world. The solid strata have been disturbed, and placed in every conceivable position, curved, inclined, and perpendicular. Vast masses of them have been shattered to

fragments, and transported to form new combinations far remote from their original site. From the deep recesses of the globe, immense quantities of matter have been made to boil over, even at the highest elevations, and pour and spread themselves out on the surface. Thus has the surface of our planet attained the beautiful and beneficial variation of level it now presents: thus have the materials of which it is composed been mingled and prepared for ten thousand useful purposes. Thus all the mineral treasures we procure out of the bowels of the earth have been brought within the reach of human art and labour. And thus, in a word, have all the beauty, variety, and riches of our world been attained. The plants that clothe, the animals that inhabit its surface, have all found their appropriate abode and sustenance; and, most of all, man finds this earth fitted for his habitation and convenience, for his utmost activity, and his high advancement. In the earthquake and volcano, we find the mitigated types of those forces, which in remote geological eras probably acted with far greater energy, and through a far wider range of extent; and we learn that in the wonderful economy of infinite wisdom, the violent and seemingly disastrous forces to which the elements of nature are sometimes subjected, work out, equally

with their more gentle and regular course, beneficial results.

The coal strata have, of course, participated in the mighty effects of these disturbing agencies. They, together with the rocks on which they repose, have been elevated from their originally low position in the geological series, till they are found upon or near the surface of the earth. The formations which may have been deposited upon them, having been fractured and heaved off, are scattered in new and far distant combinations. In some instances, the strata, among which the coal was originally deposited, have been elevated in mass, without fracture, or altered inclination. In such cases, the coal, with the accompanying beds of clay or shale, is found to occupy the whole original cavity, in a curve entirely correspondent with that of the hollow where it was first produced, and which by successive depositions is at length quite filled up. In other cases, and generally where coal beds are extensive, the strata have been fractured and disturbed by the forces which have heaved them; but even these dislocations and irregularites are found by the miner to answer valuable ends, and to bring the object of his pursuit more within the reach of his operations. When the strata are made to assume a highly inclined position, approaching more or

less to the perpendicular, then the upper edge is brought near the surface, and mining operations are proportionally facilitated. But if the strata pursued this highly inclined course without interruption for a great distance, they would penetrate so deep into the earth, as to render it no longer practicable to work them. As if with the intention of obviating this difficulty, the strata are often found fractured, the dip interrupted, and the basset edge of the coal brought a second time nearer the surface.

Sometimes, what are technically called *faults* occur: the strata have been broken, and one side of the fracture thrown down or up, so as to be found, even to the depth of several hundred feet, out of the level of the corresponding strata on the other side the break. Vast dykes are also interposed between the fractured ends of the broken strata. In these cases the strata have not only been broken, but by the same disturbing force parted asunder to distances, varying from a few inches to several feet. Into these fissures, or chasms, foreign substances have been introduced: in some instances, firm, indurated clay; in others, hard, compact sandstone. By these dykes the water draining from the strata which incline towards them, is headed up, and its further course effectually stopped. Then the strata

on the other side of the dyke, which, of course, decline from it, are preserved dry, and can be wrought with comparative ease, as being protected from those irruptions of water into the works which are among the most formidable obstacles the miner has to encounter. These dykes are, in some instances, of extraordinary length and thickness, and filled with rock of an undoubted igneous origin, and which has evidently been poured into the fissure filled by it, in a state of fiery fusion, as the strata on each side, to the distance of several feet, plainly show the action of fire: the coal being burned into coke, or even a sooty ash, and the clay or shale being converted into flinty slate.

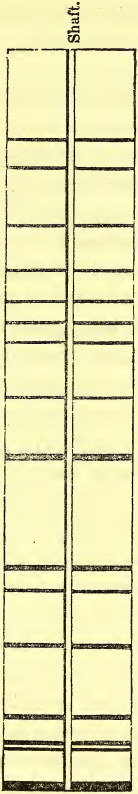
One of these remarkable basalt dykes extends through Yorkshire and Durham, to the length of sixty miles, with a thickness varying from thirty to sixty feet. There is a high probability that the same fiery force, acting at unknown depths below the rocky crust of the earth, produced both this immense chasm in the coal strata, and the melted lava with which it was filled, and also forced upward the burning mass through the whole extent of the fissure, and even in some places caused it to flow over on the surface, producing an overlying cap of basaltic rock, which is yet distinctly to be traced.

It is obvious that the power of man to penetrate into the rocky crust of the earth is very limited. At every successive fathom of depth to which he descends, the difficulty of raising to the surface the substances he disturbs becomes greater. Such minerals, also, as are useful or necessary to him, are always intermixed and buried with such vast quantities of other substances of no value, which must nevertheless be removed to obtain the object of his search, that of all human labours, mining is, perhaps, the most difficult, expensive, and hazardous. It must, therefore, be obvious, that had not the operations of nature preceded and facilitated those of art, neither coal nor any other mineral treasure could ever have been extracted out of the strata of the earth. As the result, however, of numerous successive geological convulsions, there is brought to the surface, so as to be accessible to man in different localities, almost every substance of which the solid crust of the globe is composed. From their recesses, heaved up from the very foundation of this rocky fabric, are brought up the granites and the slates required for massive, enduring architecture; the porphyries and marbles for splendid structures, magnificent columns, and noble statues; gold and silver, and precious stones, to minister to the commerce or splendour of man;

the coal and salt, and the lime and iron, so essential to the whole economy of human life in its civilized and advanced states.

But with all the aids presented by nature, or discovered by science, to facilitate the operation, mining is still a laborious, perilous, and expensive labour. In mining the coal, the first proceeding is, of course, to sink a perpendicular shaft. These shafts are sunk to the depth necessary for reaching the seams of coal, which are of a thickness and value to repay the cost and labour of working. The depth at which such seams are found, is, of course, very different in different localities. In many cases it amounts to a thousand feet; and one shaft, recently sunk near Sunderland, has been carried to the enormous depth of 1,800 feet. This has penetrated through beds of limestone and sand stone, which there overlie the coal strata. But it more frequently occurs, that the shafts pierce through successive beds of shale, clay, clunch, and such substances, of varying thickness, seldom amounting to six feet.

These beds are analogous in their material substance, and manner of deposit, to the strata between which the coal seams are immediately placed; and seem to indicate a similar origin, as being all probably deposited by successive inundations of turbid waters, charged with the clayey



Soil and clay.
Freestone and grindstone post.
Coal.
Blue metal stone.
Coal.
White and grey post.
Soft blue metal stone.
Coal.
White post girdles.
Whin.
Coal.
Soft girdle.
Coal.
Stony white post.
Coal.
Coal.
Grey post.
Coal.
Stony white post.
Black stone.
HIGH MAIN COAL.
Grey metal stone.
Blue ditto.
White post.
Coal.
Coal.
White post, etc.
Coal.
White post.
Whin.
Coal.
Coal.
White post, etc.
Mill stone.
LOW MAIN COAL.

matter which now forms these beds. The engraving on page 87, is a section of coal strata, from a drawing by a pitman in the Nightingale Pit, at St. Anthony's Colliery. The total depth is eight hundred and eleven feet, six inches.

When the workable coal has been reached, the miners proceed to cut main courses through the stratum, laterally, and as we should say horizontally, but in fact with a dip, or decline, to that point of the field which is found by observation to be the lowest. This is to effect the drainage of the mine, which is an operation of the utmost importance, as it is impossible to cut down into the earth, without opening a channel, which the waters, every where existing in the strata, will of course follow. At this lowest part of the mine a well is sunk, into which, by proper channels, all the waters, disengaged in the course of excavation, are conducted, and out of which they are raised by powerful force-pumps worked by steam, either to the surface, or to lateral drifts opened to carry them off, at convenient elevations in the shaft, sunk expressly for the purpose of pumping and drainage.

The workable seams of coal being thus at length reached, and the necessary preparations for preserving the pit dry being made, the miners proceed to excavate the coal, generally in straight

galleries, leaving either strong pillars, or continuous thick walls of the coal undisturbed, to serve as props for the roof, to support the enormous weight of the superincumbent mass of strata. As the coal is quarried, it is conveyed, generally by horses, to the bottom of the shaft, up which it is rapidly drawn by machinery placed at the surface, and worked by steam or horse power. The miners carry their lateral works, branching off in every direction from the original shaft, over a very wide extent. One colliery near Whitehaven is said to extend a thousand yards under the sea, at a depth below its bed of six hundred feet. Where the seam of coal wrought is thick, and the excavated galleries of course lofty, these subterranean scenes of human courage and labour present, when lighted up, a magnificent spectacle.

The writer will not weary his readers with long and tedious moral reflections on this subject, but he cannot satisfy himself without a concluding reference to the wonders of the material world, so fruitful in evidences of design, and of merciful provision for the wants and pleasures of sentient beings. Astronomy, natural history, and chemistry, have yielded a rich, an inexhaustible treasure of amazing facts, illustrative of the power and glory of our Maker, of the wisdom and

resources of supreme benevolence. Geology, though long regarded with suspicion by many devout minds, for which some occasion was doubtless given in the wild guesses and fanciful theories, put forth with so much confidence by many of its votaries, is now taking its place among the more exact sciences. It has been subjected to the inductive regimen. Facts are accumulated. Inferences are deduced from them with care, and are tested by an application of all the observations that can be made to bear upon them.

This science is thus becoming another wonderful proof of what the patient and persevering sagacity of man can discover, when employed to explore the various regions of the material universe. But it is also becoming, what is far more important, another fruitful source of the facts and considerations which demonstrate the wisdom and goodness of God. The preparation of the solid crust of our globe, for the habitation and welfare of man, is seen to have been as much an end pursued by the application of a long train of surprising changes and means, as the order and safety of the heavenly bodies are secured by the wonderful contrivances of gravitation; or the life and growth and reproduction of plants and animals by the wonders of

organization, with all its associated arrangements and operations. In the great temple which the Christian votaries of physical science rear to Him who created matter, and gave it all its forces, forms, and laws, the astronomer, the botanist, the chemist, the geologist, may, through Divine grace, each at his respective altar, offer the same sweet incense of adoring wonder and gratitude: each bring from his peculiar department of research facts of endless variety, but of equal power, to convince and delight the understanding, to move and elevate the affections. Nor need this be deemed a rival temple to that reared at the command and by the light of revelation. In both, the same God is worshipped by varied, but not opposing lights. The same votaries may frequent both, and carry from each to the other augmented devotion; his worship, under the united influence of the Divine works and word, sanctified by the Holy Spirit, becoming continually more enlightened, elevated, and pure.

CHAPTER V.

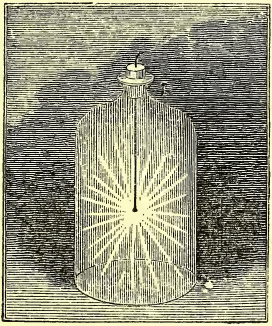
THE CANDLE.

COMBUSTION—FLAME—CAPILLARY ATTRACTION.

The candle, so commonly used in supplying light after the great orb of day has ceased to illuminate our hemisphere, may lead to many interesting inquiries and reflections.

When any substance gives out heat and light simultaneously, and suffers, at the same time, a chemical change in its constitution, it is said to be in a state of combustion. This definition may appear difficult to be understood, but may be easily illustrated, and will assist us in our future explanations. Coal and wood, when burned in the open air, give out heat and light, and are then said to be in combustion. There are many substances which can never be placed in this condition, although exposed to very high temperatures; and there are other substances, such as the metals, which are not seen in a state of combustion, under ordinary circumstances, and yet are really combustible substances.

The following simple but beautiful experiment will prove the truth of this assertion. Take a small iron wire, and twist it into the form of a corkscrew. Then take a glass jar, open at the bottom end, having a cork at the top, and put the wire through the cork, and fill the jar with



Combustion of Iron Wire.

oxygen gas. Then raise the temperature of the wire till it is red hot, or place on its end an ignited piece of wood dipped in tallow, and plunge the wire into the gas. It will immediately suffer combustion, throwing out vivid sparks in all directions. The oxygen combines with the iron, forming an oxide of iron.

When a substance burns in the atmospheric

air, it combines with the oxygen; and without a supply of that gas, there can be no combustion. It was supposed by Lavoisier, and others of the old chemists, from observing the phenomena of combustion in the air, that whenever oxygen unites with any body, combustion is produced. This, however, is not the case; for the rust on iron, or steel, is produced without combustion, and yet it is occasioned by the combination of iron and oxygen.

Those substances which are necessary for combustion, and yet are not combustible, are called supporters. They are four in number, and are all simple substances—oxygen, chlorine, iodine, and bromine. "Sulphur and phosphorus occasionally act the parts of supporters. When sulphur, in a liquid state, is made to combine rapidly with copper, or zinc, or iron, and, perhaps, also with some other bodies, it becomes solid at the instant of union, and the new compound becomes red hot, and exhibits all the phenomena of a short combustion. When liquid phosphorus is brought into contact with hot lime, barytes, or strontian, a rapid combination takes place, and all the phenomena of a brilliant combustion present themselves."

These remarks will, it is hoped, render our explanation of one instance of combustion, the

burning of a candle, more easily understood than it could otherwise be.

A candle is composed of a cotton wick, surrounded with wax or tallow. Both these are necessary, and also the contact of the atmospheric air, for the process of combustion. Let us, however, take a piece of tallow, and placing it in an iron spoon, hold it over the fire. It will soon melt, and when in a fluid state, bring a lighted piece of candle to it, but it does not burn as might be expected. Hold it again over the fire till a vapour rises from it, then bring the light again to it, and it instantly catches fire. From these experiments, therefore, it will appear, that in order to produce the combustion of wax or tallow, a heat must be given to it sufficient to convert it into a vapour, when it becomes very inflammable. The object of the wick is now evident. When the cotton is lighted, it becomes red hot, and the tallow, or wax, at the top of the candle, is melted and drawn up between the threads. It is then exposed to an intense heat, which vapourizes, and, at the same time, inflames it.

A knowledge of another fact is now required. If we dip a broad tube—for instance, a lamp glass—into a liquid, the liquid will rise in it to the height of the surface of the fluid without, but it will

not rise higher. If, however, we thrust a small, or capillary tube, so called from *capillus*, "a hair," and meaning, therefore, a hair-like tube, into a liquid, the liquid will, in certain cases, rise higher than the fluid without; and this is owing to what is called capillary attraction. The fact is, that if the liquid be water, and the tube glass, the glass will draw the water up, from the attraction, or liking it has for that fluid; and, indeed, the liking seems to be mutual, for if water be spilt on a clean piece of glass, it does not form itself into drops, like mercury, which dislikes it, but spreads itself so as to gain as large a surface of contact with the glass as it can.

In like manner, the candle continues to burn from capillary attraction. The cotton threads of the wick, being laid side by side, leave little spaces between each other: thus there are so many tubes, which, as the tallow is melted, attract it upwards, and cause the candle to give forth its light. When the candle is blown out, a disagreeable smell is produced: this is occasioned by the unburnt vapour which is escaping, and may be seen to rise from the top of the wick. If a light be brought near, it instantly ignites again. The quantity of vapour formed and consumed, must depend on the intensity of the heat supplied by the wick, and, consequently,

a very fine thread of metal is sometimes inserted, and this being at a red heat causes a greater consumption of tallow, and the more perfect consumption of the vapour that is formed. The substance of which the wick is formed, must be chosen according to the purpose for which the candle is to be used. The rush-light is so called, because the wick is formed of a rush.

It has been already stated, that atmospheric air is necessary for the support of combustion, and this may be proved by many simple experiments. Take any large glass vessel, a tumbler, if no larger can be obtained, place a piece of lighted candle under it, and fix it firmly upon the table, so that no air may enter. The flame soon grows more and more feeble, and in a short time goes out. The same thing would happen in an apartment, if there were not a constant supply of fresh air entering from various crevices, the door, or the windows. A fire lighted in a close room would soon consume all the oxygen of the contained air, and would then die away. The same principle is necessary for the support of animal life. The people who died in the Black Hole of Calcutta, were deprived of life from want of pure atmospheric air. The oxygen of the atmosphere is constantly imbibed, and performs a most important duty in the

animal economy. Withdraw it, and death ensues. The constant supply of oxygen from the atmosphere, for the support of respiration and combustion, is beautifully provided for. When the temperature of air, and, indeed, all vapours and gases, is raised, it expands, and consequently becomes lighter, bulk for bulk, than it was previous to its increase of heat; and, in all apartments, some provision should be made for its escape. The cold air, on the other hand, rushes in to occupy its place: so that, on the surface of the earth, we are always supplied with air of nearly the same density.

Let us now see how the air acts upon the burning candle. It surrounds the flame, and by conduction the heat is communicated to it, so that there is a constant current of hot air ascending, which urges the flame upwards, causing it to have a sharp-pointed form. It is for this reason that flame always ascends. The disposition to ascend is so strong, that even when the gas-light burners are made in the form of a star, the flame which is intended to go downwards, takes a curvilinear, or crooked form, although there is a considerable power in the gas, forcing it in the downward direction.

There are many interesting experiments, which will show the influence of air, or rather the

oxygen of the air, as a supporter of combustion; and that the intensity of heat is increased by a liberal supply of that substance.

When a candle is blown out, the upper part of the wick, or the snuff as it is called, will frequently remain of a red heat. The heat is sufficient to melt the wax, and even to form a vapour, as may be seen, but is not sufficient to ignite it. While the wick is of a glowing heat, blow suddenly upon it, or raise it rapidly in the air, and the chances are that it will light again; for the temperature of the wick is suddenly raised.

In striking a light, we have another example. A piece of steel and a piece of flint are struck together, and the concussion is so great, that small pieces of flint are knocked off red-hot. These fall upon tinder, prepared by a partial combustion of linen rag, to which it instantly communicates sufficient caloric to bring it to a red heat. Let us now take a match, properly dipped in sulphur, and apply the end to the heated part of tinder. The chances are, that it will not be ignited; but, if we blow on it, the heat is sufficiently great to cause the sulphur to inflame.

In the construction of furnaces, a good draft is an object of great importance. Bellows are

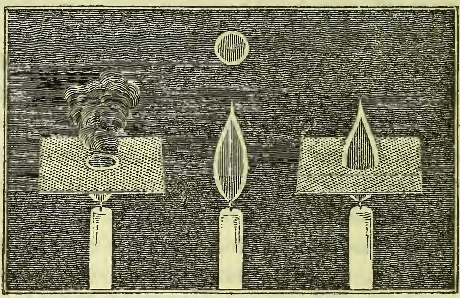
used in forges, and in fires generally, because the air thus blown upon the burning material increases the heat. When a fire is very low, wood may be laid upon it, but the heat is not sufficient to kindle the sticks. By the use of the bellows the coals themselves are made to kindle, and the wood is then ignited. You cannot light a candle with a dull red coal taken from the fire; but, if you blow upon it, the heat becomes sufficiently great to set it on fire.

We now come to consider the constitution of the flame which is produced by the candle. If you look steadily at the candle, you will perceive that the flame consists of two cones, the outer one bright and pointed; the inner one of a darker colour, and with a blunt point. The vapour, which is formed all round the outside of the wick, is burnt, and produces the bright-coloured flame; but that which rises immediately above the centre of the wick, and forms the dark-coloured cone is an unburnt vapour. To this part no air can get, and it is on that account it will not burn. The surrounding air is consumed in forming the outer flame, so that the interior vapour has no chance of being consumed. In proof that this is the case, we may examine the flame of the argand, or dining-table lamp. In this lamp, the wick is a cotton r'ng instead of a string;

and it is placed upon a circular rim of brass, fitting into a cavity, connected by two arms with the reservoir of oil. The level of the cotton is above the level of the reservoir, so as to prevent the oil from being thrown out of the circular cavity when being moved, and to give facility for the operation of the capillary force, of which we have already spoken. The interior of the cavity holding the wick is thus filled with air, and each side of the cotton is exposed to a current which ensures the complete combustion of the vapour which is formed. In this flame, therefore, there is no dark spot. To increase the draft, and to secure a regular current of air, a glass is put round the flame in such a manner as to give a free access on each side of the wick, and, at the same time, to guard the flame from any current that may be passing through the apartment. Remove the glass for a moment, and the light will become unsteady, and of a dirty red colour. If the wick be turned too high the lamp will smoke; and the same result will be produced by preventing the access of the air to the inner side of the wick.

There are two experiments by which we may prove, that the interior of the flame of a candle consists of unburnt vapour. Take a very narrow piece of cardboard about four inches long,

and hold it for a few seconds just above the wick of a burning candle, snuffed short. When removed, it will be scorched in two places in the direction of its length, the two places in which it has come in contact with the exterior cone. In the centre it will not be in the least degree affected, for there the vapour is not in combustion.



Flame of a Candle.

The same fact may be proved in another way. Take a small square of glass, and place it quickly over the flame of a candle, and you will see a circular rim of light, and within it a dark spot, as at the top of the above engraving: the circular rim is the burning vapour, and the dark spot is that which is unconsumed.

There is now only one other subject to which

it will be necessary to refer. Take a piece of wire gauze, and hold it in the midst of the flame of a candle, or a gas light, and you instantly intercept it, and the vapour will be seen to rise above in an unconsumed state, as may be observed at the left hand of the engraving. The reason is this. The metals are good conductors of heat, and consequently carry away so much of that produced by the combustion of the candle, when used as described, as to prevent the entire consumption of the vapour. To be satisfied that there is much vapour or gas thrown off without being consumed, place a lighted paper over the wire gauze, and it will be inflamed.

The value of light to ourselves in the various circumstances of life, naturally suggests to the mind, the unspeakable importance of that moral illumination, which is shed on the soul by Him who is emphatically styled "the Light of the world." Cowper has strikingly expressed the feelings of one, who, like others, shrouded by sin and in spiritual darkness, is aroused to a sense of his guilt and danger, by "the Day-spring from on high" beaming upon him.

My former hopes are fled,
My terror now begins;
I feel, alas! that I am dead
In trespasses and sins.

Ah, whither shall I fly?
I hear the thunders roar:
The law proclaims destruction nigh,
And vengeance at the door.

When I review my ways,
I dread impending doom,
But sure a friendly whisper says,
"Flee from the wrath to come."

I see, or think I see,
A glimmering from afar;
A beam of day that shines for me,
To save me from despair.

Forerunner of the sun,
It marks the pilgrim's way;
I'll gaze upon it while I run,
And watch the rising day.

And here true peace and happiness begin. For "the path of the just is as the shining light, that shineth more and more unto the perfect day," Prov. iv. 18.

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THE PHILOSOPHY

OF

COMMON THINGS.

CHAPTER I.

THE LOOKING-GLASS.

MODE OF MAKING LOOKING-GLASSES—FRAMES AND THEIR GILDING—ALLUSION TO MIRRORS IN THE SACRED WRITINGS—VARIOUS SUBSTANCES USED FOR SUCH PURPOSES—GLASS OF RECENT DATE—LAWS OF REFLECTION—HAND MIRRORS—THEIR EMPLOYMENT FOR THE PRACTICE OF IMPOSTURE.

THE looking-glass in common use, is a plate of that material, erroneously said to be silvered; for not a particle of silver is employed. The process is really as follows. A piece of tin foil of the size required, is stretched on a flat table, and on it mercury is rubbed. As soon as the two substances begin to unite, a fine surface is produced. A plate glass is then carefully slid on the foil, so as to sweep away that part of the mercury which

has not combined with the tin. Weights are then placed on the glass, and the amalgamated foil is thus made to adhere to its surface. The success of the operation depends on the completeness with which it is performed; for should the smallest particle of dirt be on the glass, it will prevent the adherence of the amalgam. It is reckoned that about two ounces of mercury will cover three square feet of glass.

The frames of looking-glasses are of various materials. Sometimes the wood is plain, as in such articles of an inferior order. At other times, it is carved, bearing on it various ornaments, wrought by tools specially provided for such purposes. A practice of recent origin is, to have wooden moulds, in which various ornaments are indented, and a soft substance is pressed into them, like wax into the engraved impression on a seal. The soft substance, consequently, takes the form which the mould is adapted to give; and becoming hard speedily, is attached by glue to the frame, thus giving it an appearance which could formerly be obtained only by carving.

The frames of looking-glasses are, also, frequently gilt: a few words on the mode in which this is done will not be out of place. First of all, the wood is covered two or three times with a composition of boiled linseed oil, and carbonate

of lead. When this is dry, a thin coat of gold size is laid on. In about twelve hours afterwards, this also will be dry, and the artist may then apply the gold leaf. For this purpose the metallic leaf being cut into convenient sizes, each strip is taken upon the point of a small brush, and applied to the various parts of the frame. It is then gently touched with a ball of soft cotton, and fixed to the size. In a few minutes it will be so firmly attached, that the loose pieces of gold-leaf may be taken off by a large camel's hair brush.

The looking-glass is designed to present a natural image of any object placed before it. All images are not, however, accurate representations of the bodies from which they are cast. The case of shadows is one with which all are familiar. Cowper strikingly says:—

> " 'Tis morning; and the sun, with ruddy orb
> Ascending, fires th' horizon; while the clouds,
> That crowd away before the driving wind,
> More ardent as the disk emerges more,
> Resemble most some city in a blaze,
> Seen through the leafless wood. His slanting ray
> Slides ineffectual down the snowy vale,
> And, tinging all with his own rosy hue,
> From ev'ry herb and ev'ry spiry blade
> Stretches a length of shadow o'er the field.
> Mine, spindling into longitude immense,
> In spite of gravity, and sage remark

That I myself am but a fleeting shade,
Provokes me to a smile. With eye askance
I view the muscular proportion'd limb
Transform'd to a lean shank. The shapeless pair,
As they design'd to mock me, at my side
Take step for step; and, as I near approach
The cottage, walk along the plaster'd wall,
Prepost'rous sight! the legs without the man."

It is not possible to look into many mirrors without becoming acquainted with the fact that the images they present are not alike. Images may be magnified, or diminished, or distorted representations may be given of the bodies from which they are produced; and this will mainly depend on the figure of the reflecting surface.

The fact on which the looking-glass is founded must have been familiar to the earliest inhabitants of the earth. Accustomed to wander over any country, whether cultivated or not, it must have frequently attracted their attention. Every river and lake would be seen reflecting the images of the mountains, the trees, the plants, the animals, and no less clearly that of the human being, who leaned over their surface, or bowed to sip of their waters. But, if no other natural object had been observed, the appearances of the heavenly luminaries reflected from the surface of water could not have passed unnoticed. Homer, and other ancient poets, frequently allude to this, and similar

effects; nor have they been overlooked by those of our own times. Thus Sir Walter Scott says:—

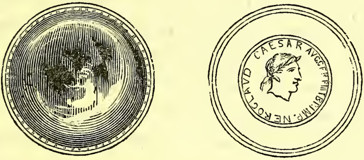
> "Late when the autumn evening fell
> On Mirkwood—Mere's romantic dell,
> The lake return'd in chastened gleam,
> The purple cloud, the golden beam;
> Reflected in the crystal pool,
> Headland and bank lay fair and cool;
> The weather-tinted rock and tower,
> Each drooping tree, each fairy flower,
> So true, so soft, the mirror gave,
> As if they lay beneath the wave,
> Secure from trouble, toil, and care,
> A world than earthly world more fair."

The invention of mirrors would naturally follow an acquaintance with the fact of reflection. The earliest allusion to them will, of course, be found in the sacred writings. Thus we read in Exodus xxxviii. 8, that Moses "made the laver of brass, and the foot of it of brass, of the looking-glasses of the women—which assembled at the door of the tabernacle." The word glass, used in this and other instances, is obviously not correct. A metallic mirror is clearly intended. Whether the stock of copper in the camp was exhausted in the other works of the tabernacle, or whether the mirrors of the women were employed from the metal of which they were formed being superior, we are not informed. In the sacred record we have satisfactory evidence of their very early use.

Ingenuity must have been exercised in giving a polish to hard substances, such as stone. Ancient authors tell us of slabs or pannels fixed, by way of ornament, in walls and wainscotted apartments. The Romans preferred for such purposes, a stone which has been identified by Beckmann, as that which is now called Icelandic agate. Stone mirrors would be the natural products of the same taste. Of these, therefore, we also read in early times; nor are instances wanting of a later date. The Spaniards found, amongst the people of America, plane, concave, and convex mirrors of a similar substance. Some, superior to others, were made of a mineral called Incas' stone, which seems susceptible of a high polish.

Hard white metal would be used for the same purposes. Steel appears to have been employed at a remote period, and mirrors of this description are still used in Egypt. Next to this in adaptation is silver, and mirrors of this substance are generally mentioned amongst the Greeks and Romans. "In the Roman code of laws," says Beckmann, "when silver plate is mentioned, under the heads of heirship and succession by propinquity, silver mirrors are rarely omitted; and Pliny, Seneca, and other writers, who inveigh against luxury, tell us, when ridiculing the extravagance of that age, that every young woman

in their time must have a silver mirror. These polished silver plates may, however, have been very slight; for all the ancient mirrors preserved in collections, which I have ever seen, are only covered with a thin coat of that expensive metal." Silver mirrors were superior to those of other metals which were sometimes employed.

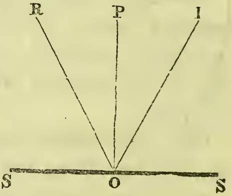


The above engraving is a copy of a Roman mirror of brass. The reflecting side is concave, and lightly polished; and on the back is an outline of the emperor Nero's head, with a Latin inscription.

Pliny also refers to attempts made at Sidon to form mirrors of glass, but in what way he does not explain. It is evident, however, that unless objects presented to them, were illuminated in a very high degree, the images which they formed must have been very faint and unsatisfactory. There is no account of glass mirrors till the thirteenth century. A century later they were very scarce in France, while those of metal were commonly used. Even

Anne of Bretagne, queen consort of Louis XII., had one of this description.

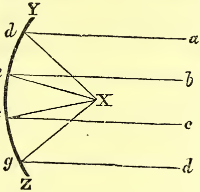
The laws which govern the reflection of light were partially understood at an early period in the history of science; but they are much more accurately known in the present day. When a ray of light falls on a bright polished surface, a part of it is absolutely lost or stifled in the substance, and another and larger part is reflected. Now, it is frequently necessary to know in what direction the ray will be reflected: and by the application of one law, this may always be done. The simplest case will be taken for the purpose of illustration.



Let S S be a plane polished surface, such as may be obtained by a looking-glass, or a polished plate of metal. Let I O be a ray of light, falling upon this plane mirror: it will suffer reflection, and it is required to know in what direction that will be: we will assume it to be in the line O R. The lines I O and P O form the angle I O P, and that is called the angle of incidence. Now, it is found that in all cases the angle of reflection, which is P O R, is equal to it. Hence, the law is expressed by

saying, "The angle of reflection is equal to the angle of incidence." This is true, whatever may be the direction of the incident ray, except when perpendicular, and it is then reflected in the same line.

From this one law it is easy to trace the effect which would be produced by the reflection of light from mirrors of differently formed substances. One or two cases may be mentioned, as explaining the application of the law.



When parallel rays of light fall on a concave surface, they are reflected, converging and meet in a point called the focus X. Let Y Z be a concave mirror, and *a b c d* several rays falling upon it, at the points *d e f g*. On whatever part of the surface the ray falls, the same thing will happen, and all the reflected rays will converge, and have some point of intersection. A concave surface may, in fact, be considered as a vast number of plane surfaces, inclined to each other. The point where the rays meet after reflection, has been called the focus, from a Latin substantive, signifying a fireplace: because, when a concave mirror is exposed to the sun's rays, so great a heat is produced at

that point, that an inflammable substance will be consumed.

When parallel rays fall upon a convex surface, and are reflected by it, they are thrown off in diverging lines; this fact the reader will be able to illustrate by applying the law already explained.

There are two circumstances with regard to the images formed by plane surfaces, such as looking-glasses, which may be mentioned. When an object is viewed in a plane mirror, the image appears at the same distance behind the mirror as the object is actually before it. This illusion is so strong, that both men and animals, when they first see themselves, evince considerable surprise. Birds have their peculiar passions remarkably excited by viewing themselves in a mirror. If a large looking-glass be placed before a cock, it is almost certain that he will prepare himself for combat; and, unless prevented, very speedily demolish the cause of his wrath. Another circumstance worthy of remark is, that an object viewed in a plane mirror, appears but half its true size.

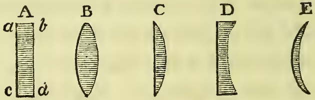
Cylindrical mirrors are of very little use in the construction of optical instruments, but are ground for the purposes of amusement. When any one views himself in one of these, if the direction of the axis of its concavity be perpendicular to the

horizon, his visage will be uncommonly distorted, the breadth of his face being greatly diminished, and the length apparently increased as much.

Turning the mirror a quarter round, the opposite extreme takes place, the image much resembling a piece of paper with two lines drawn upon it, one in black ink, the other in red. The eyes are elongated, so as to resemble the black line, and the lips are red; added to this, the extraordinary breadth of the countenance, and the ungovernable obstinacy of the image, are very laughable. If the mouth be opened, still the longitudinal one is kept shut, and only a thin white line is seen to run parallel along the centre of the red one, and that is produced by the teeth. "I removed," says one of the earliest experimenters, "the mirror a greater distance from my face, and then put my finger on the right side of my nose: the image then put his on the left side of his nose. I could contain no longer, but gave vent to my inclination by a loud fit of laughter. Unhappy being! for the image now opened his mouth to such an astonishing extent, and his long countenance seemed so dreadfully convulsed with some uncommon passion, that I willingly let the mirror fall to the ground, determined that I would never look into another."

Many beautiful natural appearances are caused by the reflection of light. The rainbow, haloes, twilight, and the colours of clouds are of this description.

In consequence of what is termed atmospheric refraction, the rays of light are bent, and actually reach the eye of an observer, before the sun is above the horizon. But when the refraction ceases to bring the rays to any part of the earth's surface, it is still illuminated by reflection from the clouds; and to this circumstance we may trace the origin of twilight.



A, a plane mirror, with two plane parallel surfaces *a b c d*. B, a convex mirror. C, a plane convex mirror. D, a plane concave mirror. E, a meniscus, having one surface convex and the other concave.

Mirrors of various curvatures are employed by opticians, generally in connexion with lenses, in the construction of microscopes, telescopes, and other philosophical instruments. By the use of these, we are able to examine objects under

different circumstances, and enlarge our information concerning the nature and design of physical existence. Many other equally interesting subjects will be suggested to the thoughtful reader, by a consideration of the looking-glass.

Sir David Brewster, in his work on Natural Magic, has clearly shown how generally the use of the concave mirror, aided the impostures of former ages. "The monarchs and priests of ancient times, carried on a systematic plan of imposing upon their subjects: a mode of government which was in perfect accordance with their religious belief; but it will scarcely be believed that the same delusions were practised after the establishment of Christianity, and that even the Catholic sanctuary was often the seat of these unhallowed machinations. Nor was it merely the low and cunning priest who thus sought to extort money and respect from the most ignorant of his flock: bishops and pontiffs themselves wielded the magician's wand over the diadems of kings and emperors; and, by the pretended exhibition of supernatural power, made the mightiest potentates of Europe tremble upon their thrones.

"Those who have studied the effects of concave mirrors of a small size, and without the precautions necessary to ensure deception, cannot form an

idea of the magical effect produced by this class of optical apparitions. When the instruments of illusion are themselves concealed; when all extraneous lights, but those which illuminate the real object, are excluded; when the mirrors are large, and well polished, and truly formed, the effect of the representation on ignorant minds is altogether overpowering; while even those who know the deception, and perfectly understand its principles, are not a little surprised at its effects. The inferiority in the effects of a common concave mirror, to that of a well-arranged exhibition, is greater even than that of a perspective picture hanging in an apartment, to the same picture exhibited under all the imposing accompaniments of a dioramic representation.

"It can scarcely be doubted, that a concave mirror was the principal instrument by which the heathen gods were made to appear in the ancient temples. In the imperfect accounts which have reached us of these apparitions, we can trace all the elements of an optical illusion. In the ancient temple of Hercules at Tyre, Pliny mentions that there was a seat made of consecrated stone, 'from which the gods easily rose.' Esculapius often exhibited himself to his worshippers in his temple at Tarsus; and the temple of Enguinum, in Sicily, was celebrated as the place where the goddesses

exhibited themselves to mortals. Iamblichus actually informs us, that the ancient magicians caused the gods to appear among the vapours disengaged from fire; and when the conjuror Maximus terrified his audience by making the statue of Hecate laugh, while in the middle of the smoke of the burning incense, he was obviously dealing with the image of a living object dressed in the costume of the sorceress."

With such facts it is well to be acquainted, since statements have been made in later times, and even in our own, of various prodigies; which an intelligent mind will not fail to trace to some natural power, or to some practice of imposture; while one that is ignorant may be grossly deluded.

A reference to the epistle of the inspired apostle James, may properly close this account. When exhorting us, in common with those to whom he first wrote, to "receive with meekness the engrafted word, which is able to save" the soul, he says: "But be ye doers of the word, and not hearers only, deceiving your own selves. For if any be a hearer of the word, and not a doer, he is like unto a man beholding his natural face in a glass: for he beholdeth himself, and goeth his way, and straightway forgetteth what manner of man he was," James i. 22—24. How important

is it, then, that truth should exert in our minds and hearts a practical influence, leading us to exercise faith in the adorable Redeemer, and constantly to implore the sanctifying power of the Holy Spirit. For "whoso looketh into the perfect law of liberty, and continueth therein, he being not a forgetful hearer, but a doer of the work, this man shall be blessed in his deed," James i. 25. May this happiness be enjoyed by every reader of the present volume!

CHAPTER II.

THE TEA-KETTLE.

THE TEA-KETTLE ILLUSTRATES MANY SCIENTIFIC FACTS—IT CAN ONLY BE MADE OF CERTAIN SUBSTANCES—REASONS FOR THIS—EFFECT OF BRIGHT SURFACES—HEAT REFLECTED AND RADIATED.

The tea-kettle is found in every family in England. When of bright copper, placed on a fancy trivet, hung upon the top-bar of the stove, it is frequently deemed an heir-loom. Often has its familiar, yet monotonous hum soothed the mind to reflection, and called forth many a remark when there has been a gathering of the domestic circle around the social hearth; and yet it may not, perhaps, have been thought that the tea-kettle illustrates many important scientific facts.

It is hardly necessary to premise, that a tea-kettle, or any vessel intended to contain water for the purpose of boiling, must be made of some substance which is incapable of liquefaction at the temperature of a common fire. Lead would be an unfit substance, because it melts at a comparatively low degree of heat. Coal would be

equally inapplicable, because it would suffer combustion; and various substances, otherwise not improper, must be rejected on account of their porosity. Any substance to be suitable must, therefore, have the property of conducting heat, and of resisting liquefaction, or combustion.

Some substances, it may be remarked, conduct heat in a much greater degree than others; and some resist its progress altogether. A rod of earthenware, and a rod of iron, will be very unequally heated by precisely the same temperature. The metals are the best conductors of heat; and are, therefore, commonly employed in the construction of all utensils required for culinary purposes. From various experiments, it appears that silver is the best conductor; but as it is a metal of too much value to be employed for domestic purposes, copper, which stands next to it in its power of conduction, or tin, or iron, which follow in order, is used for such manufactures.

Copper is a metal of a beautiful red colour, and is so malleable, that it may be beaten into thin leaves. As an article of commerce, it is never quite pure: it always contains a little charcoal and sulphur, and frequently lead and arsenic. It is commonly obtained from the copper pyrites, or yellow copper ore, which is a compound of copper, iron, and sulphur. It is found in the

island of Anglesea, and in many parts of England, particularly of Cornwall. Copper mines have been worked in England for a longer space of time than two hundred years. Before that period, whenever the workmen met with copper ore in the tin mines of Cornwall, they threw it aside as useless, no English miner knowing how to reduce it to a metallic state. To chemical science, therefore, we are indebted for the ample supply we have of this very valuable metal. The Romans, however, were acquainted with copper; for copper was the only money used by that people till the four hundred and eighty-fifth year of their city, when silver began to be coined. In Sweden, houses are covered with this metal, as a few large buildings have been in this country: the Colosseum, in the Regent's Park, for example.

When copper is exposed to the effects of atmospheric air and moisture for some length of time, it will be covered with a greenish blue substance, which is the carbonate of copper. This substance is highly poisonous, and many persons have been killed by eating food prepared in vessels on which it had been formed. Too much care cannot be taken in keeping copper utensils perfectly clean; but it is worthy of remark, that they may be used with perfect safety if this be attended to;

for vegetable acids have no effect on the metal while hot. But, to prevent a possibility of danger, the inside of copper vessels is usually coated with tin, or some other substance.

A bright polished surface greatly impedes the conduction of heat by reflection. The laws which govern the reflection of heat, are the same as regulate the reflection of light, already noticed. When light falls upon a piece of glass, it passes through it, or, at least, a large portion of that which falls upon it is transmitted. But when the glass is silvered on one side, the light is reflected, or thrown back, being unable to pass through the metal. So, when heat is thrown upon a tin reflector, or any other polished surface, it is not conducted away, but thrown back again in a direction regulated by the form of the reflector. It consequently follows that water cannot be boiled so readily in a bright copper teakettle, as in one that is not polished. The influence of a reflecting surface, however, is not so evident when the body is in positive contact with the source of heat. But if a mirror be placed at a distance from the fire, it will so radiate the rays of heat which fall upon it, that it will acquire but little increase of temperature after a long exposure to the fire. This statement will show the necessity of having bright fire-irons; for they re-

flect the heat which falls upon them; whereas, if they were rough, they would acquire, in a little time, so high a temperature as to prevent their being touched.

It is evident from the statements already made, that there are many means by which heat may be communicated from one body to another, as by contact, radiation, or reflection. When it is to be conducted, the substance in contact with the source of heat should be such as to receive the temperature applied, without losing its solidity; while, at the same time, it must resist combustion. Copper and iron, metals which cannot be melted at common temperatures, and which are excellent conductors of heat, are, therefore, employed as tea-kettles.

When the water contained in a tea-kettle has been, for a time, exposed to a high temperature, it becomes hot, and at last boils, a column of steam afterwards issuing from the spout. It will not be unworthy of our inquiry, by what process this steam is formed. The temperature of water under common pressure cannot be raised above two hundred and twelve degrees of Fahrenheit's scale, which is always attached to English thermometers: two hundred and twelve degrees is the boiling point of water. Much heat may afterwards be communicated; but the sensible heat of

the water is not increased, for all the additional heat that is communicated is expended in converting the water into steam. When heat is not sensible to the touch, or thermometer, it is said to be latent; some persons designate it, constituent caloric. That the latter expression is very applicable, may be proved by a simple experiment.

Take two small copper vessels: in one, place water, and in the other ice, and let both be at the temperature of thirty-two degrees. In each of the vessels place a thermometer; then plunge them both into a mercurial bath, raised to a high temperature, or into a reservoir of water at two hundred and twelve degrees, with the means of keeping it at nearly the same point. Immediately the vessels come in contact with the hotter body, they begin to conduct the heat. The temperature of the water rises immediately, as seen by the thermometer in it; but the thermometer in the ice remains stationary. By the time the ice has melted in the other vessel, the water will have a temperature of one hundred and seventy-two degrees. It would therefore appear, that heat equivalent to the temperature of one hundred and forty degrees has been communicated to the ice, without raising its temperature. There is but one way of accounting for this fact, and that is,

by supposing one hundred and forty degrees of heat to be necessary for the conversion of ice into water. So, when water is converted into steam, a certain amount of latent heat must be communicated. An ounce of water could not assume a vaporous state without receiving as much heat as would raise its temperature, if sensible, nine hundred degrees.

Here, then, we see why it is colder during a thaw, than in frosty weather. When the waters of our ponds, lakes, or rivers, are frozen over, heat must be obtained from some source before the ice can be converted into water. To effect this, heat must be taken from any substance which happens to be in contact. The temperature of the atmosphere is thus lowered, to provide the constituent heat of the water during the thaw. So when water is vapourized, the temperature of the substances in contact is necessarily lowered, their sensible heat being applied in a latent state by the fluid.

It will appear from this explanation, that when the water contained in a tea-kettle, or any other vessel, has been raised to the boiling point, or two hundred and twelve degrees, it cannot be made to rise higher, for all the heat afterwards communicated is spent in converting the water into vapour. This aqueous vapour is invisible;

but when it issues from the spout of our tea-kettle, it is condensed by the atmosphere, which is of a much lower temperature, and hence it becomes visible.

When the water is poured from the kettle into the tea-pot, the source of heat is removed, and the water will begin to get cool, both by conduction and radiation. If the pot be made of a substance which is a good conductor, it will soon become as hot as the water it contains, and conduct away its heat to the atmosphere, and to any other body in contact with it. Such is the conducting power of the metals, that when a tea-pot is made of any one of them, the handle is constructed of ivory, bone, wood, or some other badly conducting substance; or, if a silver handle should be used, it is not connected immediately with the pot itself, but is separated by a small piece of ivory, or some other non-conducting substance.

Bodies are cooled by radiation, as well as conduction. Heat is capable of radiation from a hot body; that is, of passing off in rays, or straight lines, without the interference of any conducting power, in the same manner as light radiates from one that is luminous. Those substances, therefore, which radiate heat, are the most suitable to be employed for the manufacture of tea-pots.

CHAPTER III.

THE LAMP.

VALUE OF ARTIFICIAL LIGHT—EXPERIMENTS OF M. ARGAND—SINGULAR DISCOVERY—COMPLETENESS OF HIS LAMP—THE APPLICATION OF HIS PRINCIPLE TO MANY OTHERS.

Excepting the essential articles of food and shelter, there is perhaps scarcely any thing more necessary to our comfort than artificial light. Without its aid a considerable portion of time in the climates inhabited by civilized men, must be wasted in idleness; and although the privation might not be felt by the listless dwellers in the torrid zone, to us who live in the region of unequal days and nights, the want of it would operate as a check on improvement, and a great bar to the provision of the necessaries of life.

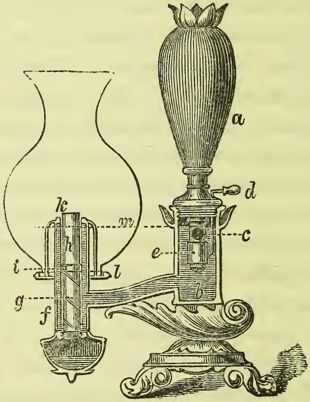
To avert these evils, various well-known means have been adopted; among which may be noticed various kinds of lamps, on which brass has been extensively employed. Of these, till a recent date, the principle of the burner was the same; and although many ingenious contrivances were adapted to this part, they all had in view the equable flow of oil to the wick, or the maintenance

of the oil, to remedy the most important defects. A great alteration, however, was proposed and perfected by M. Argand, a citizen of Geneva, many years ago.

To understand fully the nature of his improvement, it must be remembered, that a plentiful supply of air is necessary to the existence of flame. A small wick produces, of course, a small flame; but, in consequence of that smallness, almost every particle of the flame is in contact with the air, and the light is very brilliant. By increasing the size of the wick, the flame is enlarged; but then the interior portion, which is deprived of air, is but imperfectly inflamed; the light is in consequence brown and dull, and much of the oil burned passes off in smoke, without being inflamed at all. The only mode found of increasing the body of flame, without decreasing its brilliancy, was by increasing a number of little wicks, which were placed side by side in a line. This produced a good light; but it was unsightly, and troublesome to arrange, and by no means so brilliant as might have been expected from the same quantity of light in a compact form. It occurred therefore to Argand, that if this line of wicks could be placed in a circle, and a current of air admitted through the interior of the circle, while the outside air was applied to the external surface, the power of a large wick

would be obtained with all the brilliancy of a small one. This was effected in the following manner: a small tube, about three inches long, and half an inch in diameter, was soldered at one end, and within side another tube of the same length, but double the size, leaving a space between the two, open at one end and closed at the other. A wick was formed by a piece of cotton woven round without a seam, and fixed to a brass ring fitted to the space between the two tubes, and raised or depressed by a worm or groove cut in the inner tube, or by a rack and pinion. The oil was admitted to the wick by a pipe connected with a reservoir, and passing through the outer tube. Thus was formed a ring of light; but the lamp did not at first answer the expectation of the inventor: the light was not brilliant in proportion to its size, and could not be made to rise much above the wick. Every attempt to increase its light, by a more copious flow of oil, or by raising the wick, only produced a volume of smoke. This effect would have been fatal, had not what is termed "accident," discovered a remedy. This appears in the glass chimney, which, by increasing the current of air, produced a complete combustion of oil, and as great a light as could possibly be derived from the quantity consumed. This accidental discovery is thus related by the younger

brother of Argand :—" My brother had long been trying to bring his lamp to bear. A broken-off neck of a flask lying upon the chimney-piece, I happened to reach it over to the table, and to place it over the circular flame of the lamp; immediately it rose with brilliancy. My brother started from his seat with ecstasy, rushed upon me in a transport of joy, and embraced me with rapture." Thus was the Argand lamp formed:



the most important improvement discovered in artificial light, before the introduction of gas, and on which no improvement, affecting the principle, has since been made. The following description will explain it more fully :—

The reservoir *a* terminates in a neck, which screws into the upper part of the oil cistern *b*; when it is unscrewed and inverted, the oil is poured into the reservoir at the hole *c*; by moving the handle *d*, the short tube *e* is made to cover this hole, and prevent the oil from running out; and the reservoir is then screwed into its place, and the handle depressed, so as to uncover the hole, and to allow the passage of the oil into the cistern *b*. Within the perpendicular tube *f*, there is placed a smaller tube *g*, and both are closed at bottom and open at the top; the space between these contains oil and the wick *h*, stretched over the short tube *i*, rising a little above the tubes at *k*. The outer surface of the tube *g*, has a spiral groove formed round it; and a tooth in the ring or gallery *l*, entering this groove, when it is turned round, causes the tube and wick attached to it to ascend or descend, so as to regulate the flame. On account of the nature of the reservoir which contains the oil, a constant supply will be kept up, at the level marked by the dotted line *m*, both in the cistern *b*, and in the wick-tubes *f* and *g*.

The invention received almost immediately the support to which so useful a discovery was entitled. The Argand lamp was adopted by all to whom a good and steady light was desirable. Persons engaged in delicate operations, requiring

much light, as engravers and watchmakers, and who had hitherto been compelled to suspend their occupations at the approach of twilight, could now work by night as well as by day. The experimental chemist, too, was put in possession of a powerful aid in the prosecution of his investigations, by the use of this lamp, which gave a considerable and easily graduated heat, much more manageable than that of any furnace that could be constructed.

Such is a brief account of the leading principles of Argand's invention. Various improvements have since been made on the original, by the lamps now in general use as table lamps, which it would be superfluous to enumerate; all of which, however, may be regarded as improvements more of detail than principle. Indeed, the great value of Argand's invention, consists in the facility with which it can be engrafted on lamps of every variety of form and structure; while not all the beauty of design and execution, witnessed in the endless diversity of form of the lamps at present in general use, would be sufficient to produce for them any considerable notice, if they were destitute of the Argand principle. This facility of general application, has recently been exemplified in an ingenious invention, by which lamps on the Argand principle have been made to burn the

common fish oil, instead of spermaceti, which had hitherto been indispensable. This improvement, which is so desirable in an economical point of view, consists chiefly in supplying the flame with a greater quantity of oxygen, than had hitherto been effected. This is accomplished by means of apertures in the sides of the lamp, and a cap with a deflector; but in applying this improvement to lamps on Argand's principle, a larger and coarser kind of wick must be employed, and the tubes with which the burners and the wick are supplied with oil, must also be enlarged. Lamps constructed on this principle are designated solar lamps. The combustion being greater, a larger supply of air is needed to render it perfect: consequently, all the openings of the lamp are larger.

CHAPTER IV.

THE STEAM CARRIAGE.

DISCOVERY OF THE ELASTIC POWER OF STEAM—WONDERS OF THE STEAM ENGINE—SIMPLICITY OF THE PRINCIPLE ON WHICH IT ACTS—ITS APPLICATION TO TRAVELLING—LOCOMOTIVE ENGINE—EARLY AND RECENT RAILROADS.

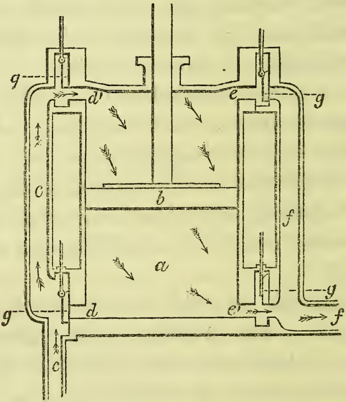
It is stated, that the use of steam, as a mechanical power, was first suggested by a tea-kettle. The lid of the kettle was observed to rise, and give escape to the confined steam, and it was then thought, that the expansive power of the same agent might be employed as a moving force.

How fully has the expectation been realized! Steam has become, indeed, a wonderful power, which in its present improved state "appears," says an elegant writer, "a thing almost endowed with intelligence; it regulates, with perfect accuracy and uniformity, the number of its strokes in a given time; counting, or recording them, moreover, to tell how much work it has done, as a clock records the beats of its pendulum: it regulates the quantity of steam admitted to work; the briskness of the fire; the supply of water to the boiler; the supply of coals to the fire: it opens and shuts its valves with admirable pre-

cision, as to time and manner; it oils its joints; it takes out any air which may accidentally enter into any part which should be vacuous; and when anything goes wrong that it cannot of itself rectify, it warns its attendants by ringing a bell: yet, with all these talents and qualities, and, even when exerting a force equal to hundreds of horses, it is obedient to the hand of a child. Its aliment is coal, wood, charcoal, or other combustibles; it consumes none while idle; it never tires, and wants no sleep; it is not subject to malady, when originally well made; and only refuses to work when worn out with age; it is equally active in all climates, and will do work of any kind; it is a water-pumper, a miner, a sailor, a cotton-spinner, a weaver, a blacksmith, a miller, etc.; and a small engine in the character of a steam pony, may be seen dragging after it, on a rail-road, a hundred tons of merchandise, or a regiment of soldiers, with thrice the speed of our fleetest horse-coach. It is, in fact, the king of machines."

The principle on which it acts may be easily understood. The following figure presents to the eye a cylinder, the inner surface of which is made perfectly true, as the term is, or as it may be explained, being of exactly the same circumference from one end to the other. In this an

iron box, or piston, works, exactly fitting the inner surface, so that no air can pass between the piston and the cylinder. Let the piston be supposed to be drawn to the upper part of the cylinder, and steam to be admitted above the piston; and it will be seen, that, by the elasticity of the steam, the piston will be driven downwards; if then, the steam be admitted below the piston, it will, provided the steam above be withdrawn, in like manner be forced upwards; and thus the rod of the piston will ascend and descend alternately. *a*, cylinder; *b*, piston; *c c*,



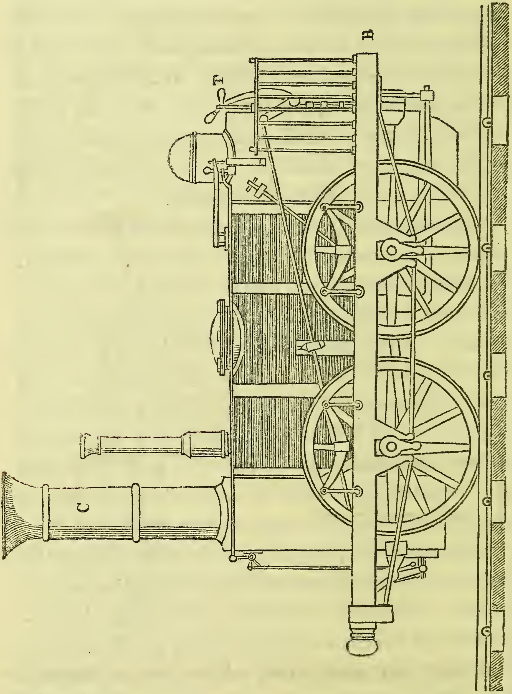
pipe, by which the steam passes from the boiler to the cylinder; *d d*, passages, to admit the steam

alternately to the upper and lower parts of the cylinder; *e e*, passages, by which the steam escapes from the cylinder through the pipe, *f f*, to the condenser: *g g g g*, slides, for the opening or closing of the passages. The arrows point out the course of the steam as rising from the boiler through the pipe, and pressing on the upper part of the piston; and, also, as passing from the lower part of the piston to the condenser. Here, then, is the origin of steam-power: its application to travelling is now to be considered.

The engraving, page 36, represents a locomotive engine, constructed on the most approved principle. Its mechanism is so simple, that a short description will be sufficient to explain its mode of acting. The principal parts of the engine are, the fire-place and boiler, which constitute the means of raising the steam; the slides and cylinder, which are the means of bringing into action the elastic force residing in the steam; and the cranks and wheels, by means of which the motion is transferred from the piston to the engine itself.

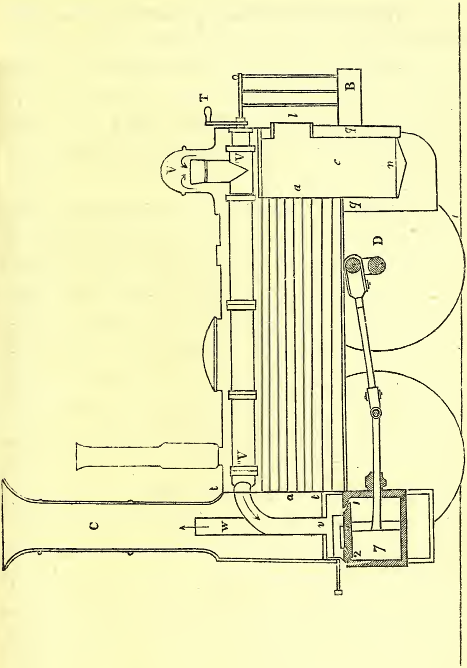
The engraving, page 37, shows the body of the machine, as composed of three distinct compartments. The one on the left, or fronting the machine, and which is surmounted by the chimney c, is separated from the two others by the partition *t t*. The two others form the boiler; both are

filled with water to near the level of the tube marked ^{1}v ^{11}v; but part of their internal space is occupied by the fire, as will be next explained.



In the hindermost compartment is placed a

square box, *e*, which contains the fuel, or forms the fire-place of the machine. Between the sides



of that box, and those of the compartment in which it is contained, a space *q q* is left, which

communicates freely with the remainder of the boiler, and which is consequently filled with water.

The fire-box *e*, being thus placed in the middle of one of the compartments of the boiler, would be surrounded on all sides with water, were it not for the aperture *l*, which forms the door of the fire-place; and of the bottom *n*, which forms the grate, the ashes falling through into the space beneath.

Near the door *l*, and in the machine, is placed a strong platform, represented by B, for the engine-man to stand upon. Directly behind the engine is attached the tender carriage, with coke and water; so that it is easy for the firemen to throw coke into the fire by the door *l*, and to let water pass into the boiler whenever it may be necessary. This supply of water takes place by means of a forcing pump, put in motion by the engine itself.

The lower part *n*, of the fire-place is occupied, as has been said, by a grate, and remains constantly open, admitting the external air required for the combustion of the fuel. The coke thrown into the fire-box, falls on the grate, and is supported by it. When the fire is lit, and the door of the fire-box shut, the flame of the combustible remains confined in the fire-box. It would have no egress, if a number of small tubes, or flues, *a a*,

were not to lead to the chimney, after passing through the whole length of the second compartment, or principal body of the boiler.

From the construction it will easily be understood, that the fire being shut up in the fire-box, and completely surrounded with water, none of its heated parts are lost. Afterwards the flame, in its way to the chimney, divides itself among all the small flues now mentioned. It thus passes through the water of the boiler, having a considerable surface in contact with it; and only escapes after having conveyed to the water as much as possible of the heat it contained. Once arrived at the right hand extremity of the tubes, the flame is in the compartment of the chimney, and escapes freely through the chimney C.

In the upper part of the boiler, that is to say in the part occupied by the steam, there is a large bent tube, V, ^{1}V, ^{11}V, which is open at the end V, and leads out of the boiler; it is by this tube that the steam is conducted into the cylinders. At ^{1}V, in the interior of the tube, is a cock, or regulator, the handle T of which extends out of the machine: by turning that handle more or less, the passage for the steam may be opened and shut at will.

The steam being thus generated in great abundance in the boiler, and being unable to escape out

of it, acquires a great degree of elastic force. If, at that moment, the cock at 'v is opened, by turning the handle T, the steam enters the tube at V, and passes along it to the entrance *v*, of the valve-box. There a sliding valve, which moves at the same time with the machine, opens a communication to the steam necessarily with each end of the cylinders. These are placed horizontally at the bottom of the chimney compartment, where the passage of the flame, and the sides of that compartment, protect them against the effect of the cold air, and keep them in a proper degree of heat.

The direction of the arrows in the engraving, marks the line of circulation followed by the steam, from its entrance into the aperture v, into the slide box. In the situation in which the slide is here represented, passage 1 is open to the steam, and consequently the piston is pushed towards.the left hand. At the following instant, passage 2 will open in its turn, and the piston will be pushed in the contrary way. When the steam has produced its effect, it passes into the tube w, and is conveyed by it to the chimney, through which it escapes into the atmosphere.

The introduction of the steam takes place at v, at a point purposely elevated, that the bubbling and jolting of the engine may not let the water of the boiler get in by the opening v.

The piston rod being set in motion, communicates a rotatory movement to the axle of the two hind wheels of the engine. This transformation of the alternate motion into a circular one, takes place after the manner of the common foot spinning wheels, by means of a crank in the axle, as represented at D. It is almost needless to add, that in proportion to the rapidity of this circular motion, so the wheels revolve, and the engine advances, dragging after it its tender of fuel and water, followed by a long train of carriages or wagons.

The idea of forming smooth surfaces for carriage wheels to roll upon, is not of modern origin; but no horse can draw with advantage on a smooth pavement: hence, in Florence, where the wheel tracks are paved with hard marble, wrought smooth and level, the horse paths are of ordinary paving. At an early period, a similar advantage was obtained in our own country, at the collieries of Newcastle, by putting down rails of hard wood for the wheels of wagons to run upon; and more recently, rails of cast-iron have been employed, and with more advantage, being much harder and more durable, than even the marble wheel-tracks of the Italians.

By using iron, we obtain a smooth, hard, and even surface, at an expense comparatively small;

and the moving power has very little more than the friction of the axis to contend against. A carriage moving under such circumstances, bears the nearest analogy to a body impelled upon the smooth surface of ice, where it is well known that the velocity which may be given by a small power is immense; what the rails want in smoothness, being compensated for by the use of wheels.

Speed and certainty of conveyance are of such primary importance in commerce, that a small increase of expense to obtain them is not material. The certainty of supply must also greatly tend to diminish the fluctuations of prices, and remove those alternations of glut and scarcity which are perpetually occurring in the markets, from contrary winds, frosts, and floods. Everything which tends to render the conveyance of goods certain, must lessen their expense to the consumer, by diminishing the amount of dormant capital, and the necessity of keeping large stores in extensive warehouses. With a good system of conveyance, too, when a sudden call does take place, the whole stock of the country becomes available at any point desired.

A cheap and regular mode of conveyance, besides rendering the produce of fertile lands accessible at a lower price to any portion of the community, also affords new markets for other articles.

It creates new sources of exchange and supply, and causes the advantage of labour and industry to spread; and it expels the idleness and indifference which engraft themselves among those people, who, without such means, barely obtain the common necessaries of life. The ordinary mode of land carriage, makes every heavy commodity so expensive, that the inhabitants of inland districts are denied the use of many things. In many places, they are nearly destitute of fuel; and while moderate exertion gives them the scanty supply of comforts within their reach, their utmost efforts scarcely do more; and, therefore, they sink into that languid state of indifference, which we find so generally prevalent in such countries.

The first railways appear to have been used in the neighbourhood of Newcastle-upon-Tyne, about A.D. 1680: the rails were of wood, resting upon wooden transverse beams, called sleepers. The wooden rails are, however, now abandoned for iron ones, of which there are an immense number branching in various directions from both sides of the Tyne, to the various coal works. The rails employed are now all of the kind called edge rails: and it appears, from experiments, that on the level rails, when they are in good condition, a force of one pound will draw a weight of one hundred

and seventy pounds; or one horse will draw twenty-five thousand, five hundred pounds' weight, including the weight of the wagon, at the rate of two miles and a half per hour. The immense advantages of railways at Newcastle, soon caused them to be spread to the mining districts of Yorkshire, Derbyshire, Wales, and Scotland; and they are now being rapidly extended over the United Kingdom, for the general purposes of trade.

CHAPTER V.

THE GAS LIGHT.

INTRODUCTION OF COAL-GAS — USE OF OIL LAMPS FOR LIGHTING STREETS — DR. CLAYTON'S DISCOVERY—VARIOUS KINDS OF GAS—MANUFACTURE OF GAS FOR PUBLIC USE—ADVANTAGES OF ITS USE—ITS EMPLOYMENT IN THE METROPOLIS.

The introduction of coal-gas, as a means of illumination, may be considered as one of the most successful applications of science in modern times. When the metropolis was lighted with oil, in common wick lamps, a great number of persons were necessarily employed in preparing the lamps. A parish which now needs but one person to superintend the gas-light, required from four to six to keep the former lamps in order; and in shops and warehouses there was a proportionate waste of time in the same offices; and, in every case, frequent failure from negligence, or the badness of the materials. By the adoption of gas as a light, all these inconveniences are removed. Two or three persons are sufficient to superintend the manufacture of gas to supply a large district; and all that is required of those who have the charge of the several burners, is to apply a light

to the stream of gas, to keep the glasses clean which are placed round them, and to prevent the access of violent currents of wind. Several interesting facts are now to be noticed, in reference to the discovery of this means of illumination and its use; while, with them, much important information may be found connected with the science of chemistry.

Whenever coal is burning in a common fire, a flame is produced. This flame arises from the combustion of coal-gas, and other vapours, set free in consequence of the heat to which the solid body is subjected. There is a very simple means by which the gas may be formed, and its properties discovered. Take a large tobacco pipe, and put a piece of good coal into the bowl, allowing the end of the tube to come into the room. After a few minutes, a vapour will be seen to issue from it; and when this has been going on sufficiently long to expel the atmospheric air, apply a lighted paper, and the gas will ignite. In this way the reader may manufacture gas for himself, although it is, unavoidably, very impure in such circumstances, and unfit for any useful purpose.

To appreciate the advantages which have been derived from the use of coal-gas, it is only necessary to go into any town where the streets are still lighted with oil. The dismal appearance

these places present, and the facility thus afforded to crime, were common to all our cities previous to the year 1810. From the accounts which are given of the introduction of coal-gas, as a means of illuminating our streets and houses, it appears that Mr. Winsior has a claim to the honour, though Dr. Clayton was the first to discover that the gas given off from coal, when heated, produced an excellent flame, suited as an artificial light. "I got some coal-gas," he says, in his communication to the Royal Society, in 1739, "and distilled it in a retort, in an open fire. At first, there came over only phlegm, afterwards a black oil, and then likewise a spirit arose, which I could no ways condense; but it forced my lute, or broke my glasses. Once, when it had forced my lute, on coming close thereto, in order to try to repair it, I observed that the spirit which issued from it caught fire at the flame of the candle, and continued burning with violence, as it issued out in a stream, which I blew out and lighted again alternately, for several times. I then had a mind to try if I could save any of this spirit, in order to which I took a turbinated receiver, and putting a candle to the pipe of the receiver, whilst the spirit arose, I observed that it caught flame, and continued burning at the end of the pipe, though you could not discern what fed the flame. I then

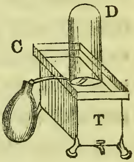
blew it out, and lighted it again, several times; after which I fixed a bladder, squeezed and void of air, to the pipe of the receiver; but the oil and phlegm descended into the receiver, but the spirit, still ascending, blew up the bladder. I then filled a good many bladders therewith, and might have filled an inconceivable number more; for the spirit continued to rise for several hours, and filled the bladders almost as fast as a man could have blown them with his mouth; and yet the quantity of coal distilled was inconsiderable. I kept this spirit in the bladders a considerable time, and endeavoured several ways to condense it, but in vain. And when I had a mind to divert strangers or friends, I have frequently taken one of the bladders, and pricking a hole therein with a pin, and compressing gently the bladder near the flame of the candle, till it once took fire; it would then continue flaming till all the spirit was pressed out of the bladder, which was the more surprising, because no one could discern any difference between these bladders, and those which are filled with common air."

The gas obtained from the distillation of coal, is a mixture of carbureted hydrogen with hydrogen, carbonic acid, nitrogen, and sulphureted hydrogen gases. These are mixed in various proportions, the quantity of each depending on the nature of

the coal employed, and the manner in which the heat is applied. It will be well, therefore, to explain the different kinds of gases of which it consists.

To obtain hydrogen gas, pour sulphuric acid, diluted with about five or six times its weight of water, on small pieces of iron, such as iron turnings, or nails. The gas will be immediately given off, and may be received in any glass vessel provided for the occasion. The gas may also be obtained, and in a state of greater purity, by using zinc instead of iron; but in this case the sulphuric acid should be diluted with eight parts of water. A very simple apparatus, which will cost but little money, is all that is necessary for this purpose. Take a thin glass flask, and having fitted it with a cork, in which a hole has been cut, insert a piece of tobacco pipe. When the materials for making the gas are placed in the flask, fix the cork in its place, and cover it over with some plastic substance: putty or clay will generally answer the purpose. As the gas rises, it must be received into some glass vessel. A glass receiver is more suitable than any thing else, and may be obtained either with a glass stopper, or a cork. Most of the gases are collected over water; when this is the case, a tin vessel, called a pneumatic trough, is used; but a small tub, or pail, will serve

the purpose as well. Take a small piece of board, as wide as your receiver, and having cut two or three holes in it, let it be fitted into the tub, or pail, and the gas apparatus will be complete. It is shown in the accompanying drawing. T is the tub; C the board, with holes, placed across it; D the receiver; E the flask.



We have now to form hydrogen gas. To do this, we must first place in the flask some pieces of zinc, and pour upon them the diluted sulphuric acid. A cork, with a pipe fitted to it, is then fixed into the neck, the opposite end being put into the water, so as to rise towards that hole over which the receiver is to be placed. We must now remove the stopper of the receiver, and plunge the vessel into the water, which expels all the air, and fills it. The receiver must then be placed as in the figure. When the chemical action between the zinc and the sulphuric acid has been going on long enough to expel all the atmospheric air in the flask, the end of the tube may be brought under the hole, and the bubbles of gas will rise into the receiver, driving out the water. In making hydrogen gas, it is particularly necessary to exclude the atmospheric air; for when the two gases are united, a most explosive compound is produced.

Hydrogen gas has a disagreeable smell, is the lightest of all gases, is fatal to animals, and though inflammable itself, extinguishes burning bodies. The following experiments may be made upon it; but great care must be taken that there is no mixture of atmospheric air; for, if this happen, an explosion will be produced when a light is brought near. It should not be tried by young, or inexperienced persons.

1. Take a small bottle containing hydrogen, and let it stand with its open mouth upwards for a few minutes; and when a lighted taper is introduced, the gas will be found to have escaped, and atmospheric air to have taken its place. This shows that hydrogen gas is lighter than atmospheric air.

2. Fill a small bladder, having a stop-cock and brass pipe, with hydrogen; press upon the bladder, so as to force out the gas, and bring a lighted candle near it. The gas will immediately take fire, and burn with a pale, feeble flame. This proves the inflammability of hydrogen, and its applicability as an artificial light.

3. Burn the hydrogen, as in the last experiment, in a glass tube, and musical sounds will be produced, the pitch being regulated by the form of the tube.

Sulphureted hydrogen may be made in the following manner. Take some powdered sulphuret

of antimony, and pour upon it about five or six times its weight of muriatic acid. When heat is applied, the gas will be given off in large quantities. It is remarkable for its extremely offensive smell, much resembling that of putrid eggs. It is inflammable, and burns silently when not mixed with atmospheric air. No animal can live in it for a minute; and it is stated that a bird died instantly in an atmosphere which contained only one part in 1,500 of the gas.

Carbureted hydrogen, sometimes called heavy inflammable air, is obtained by purifying coal gas. It gives out more light than hydrogen, and burns with a yellow flame. If the bottom of a pond be stirred up, this gas will rise up to the surface, and may be collected in an inverted jar.

Nitrogen gas is one of the constituents of common air, and may be obtained in the following manner. Put a paste, consisting of iron filings and sulphur, mixed with water, into some vessel, and over it invert a jar, containing atmospheric air; after this has stood for a time, the water will begin to rise in the receiver, and, in two or three days, the whole of the oxygen will be absorbed, leaving a quantity of nitrogen equal to about four-fifths the volume of air. The following experiments will illustrate its properties.

1. Plunge an ignited taper into the gas, and

the light will be immediately extinguished. Here is a fact showing that animals cannot breathe in it: a fact the reader will not attempt to prove, if he has formed a suitable estimate of the value of animal life.

2. If four parts of oxygen be mixed with one part of nitrogen, a compound will be formed, resembling atmospheric air, and having all its properties.

The vessels in which the coal is distilled for public use, are called retorts. They are generally of an elliptical form, composed of cast iron, and about six feet, six inches long. These retorts are so set in brick-work, that the greatest possible number may be heated equally by the same fire. Mr. Perks, who obtained a patent in 1817, for his plan of setting retorts, proposed to place twelve in a circle, with one in the centre. The methods now adopted are generally modifications of this.

Before the coal is put into the retort, a fire is lighted, and the retort raised to the proper temperature. The coal is put in with an iron semicircular scoop, and then spread evenly over the bottom: each retort taking a charge of about one bushel. When this has been done, the mouth, or open end of the retort, is closed with a cover, which is afterwards listed, so as to prevent the

escape of any gas. To each retort an iron tube is fixed, and this is connected with a large cast-iron cylinder, fixed in a horizontal position at the front of the brick-work in which the retorts are set. The gases and vapours, as they are formed, are carried away by the pipes into the hydraulic main, which contains a quantity of cold water to condense the vapours arising from the coal. As the gas passes through the water, some of its impurities are condensed, especially a portion of the tar and ammonia connected with it in its first formation. To one end of the main, and above the level of the water, a pipe is attached to carry the gas; and this is connected with a vessel called the condensing apparatus, where the tar brought from the main is still further condensed. Nearly all the ammonia is disposed of in the first vessel, on account of its strong affinity for water.

It is important that such a degree of heat should be given to the coal in the retort, as shall be sufficient to throw off all the substances capable of vapourization. If the heat be too little, the volatile substances will not be entirely disengaged; if too great, the quality of the gas will be impaired, and the retorts injured. When the distillation has ceased, the residue, which is coke, must be taken from the retorts, and a new charge

be put in. The tar is at the same time carried away by a pipe employed for that purpose.

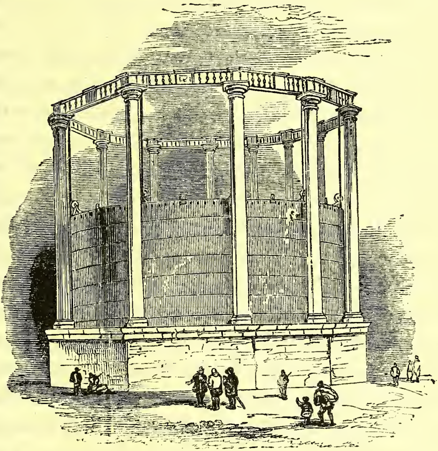
When the gas is first disengaged from the coal, its temperature is, of course, very great. Before any portion of the impurities can be condensed, and thus separated, it is necessary to reduce its temperature. This is partly done by the hydraulic main, but more effectually by the condenser. This consists of a large tank, which is fitted up with a series of pipes; the space between the pipes being filled with cold water, so that the gas in its progress has to pass over a continued cool surface. The tar is thus deposited at the bottom, and is conveyed by another pipe to a reservoir called the tar vessel. To this is fitted a number of cocks above each other. By the lower ones, the tar, which is heavy, and sinks to the bottom, may be drawn off; by the upper, the ammonical liquid.

From the condenser the gas is carried by another pipe, fitted to the top of the vessel, into the purifier. When gas was first introduced for lighting, there were many objections to its use, arising from its impurity. It was found that the copper pipes conveying it from the gasometer to the burners were rapidly corroded; that bright metallic articles in the rooms where it was burned were exceedingly tarnished, and that

an unpleasant and unwholesome atmosphere was produced. These objections were so powerful, that the importance of discovering a means of purification was evident to all who studied the subject. It was effected as follows:—The vessel in which the process is carried on is formed of cast iron, and is divided into several chambers, so formed that the gas must pass through a considerable quantity of lime and water, the liquid being kept in constant motion. The sulphureted hydrogen and carbonic acid are taken up in consequence of the chemical affinity subsisting between the substances. It is sometimes thought necessary to have two or three purifiers, as the separation of the volatile substance with which the gas is connected, must be an object of great importance.

After the gas has been submitted to all these means of purification, it is conducted into a large vessel, generally of a circular shape, called the gasometer, from which it is forced into the mains. The gasometer is of a form resembling two tubs, the smaller of which has its open end downwards, and falls into the larger. The lower end of the gasometer is fixed in the ground, and is made several inches larger than the upper, which is formed of wrought iron, and suspended by weights, passing over pulleys, and exactly balancing it.

The lower cistern, or vat, if so it may be called, is filled with water, and the upper one sinks into it when there is no gas; but as the process of manufacture goes on, the moveable part rises, and gradually receives a large quantity of gas.



THE GASOMETER.

The cut represents the improved gasometer recently erected by the City of London Gas Light Company. The reservoir is $101\frac{1}{2}$ feet in diameter, and contains 329·763 cubic feet of gas. The depth of the tank, in which the mouth of the reservoir is immersed, is twenty-two feet six inches.

The quantity of gas in this immense vessel, being considerably greater than that which fills one of the ordinary size, it is of a less specific gravity, volume for volume, according to a fixed mathematical law of proportion; and does not, therefore, stand in need, like the smaller vessel, of counterpoise weights.

One pound of coal is supposed to yield about twenty-four gallons of gas; but this depends upon circumstances. Some kinds of coal yield much more gas than others; and the manner in which the heat is applied will make a great difference. The prejudices which at one time prevented the use of gas have died away; and now it is but seldom that persons express any dread about it. A few years since, it was objected to from a fear that it was dangerous; and now the same parties employ it without any more knowledge than they had at first. Ignorance is as often the parent of dangerous confidence, as of unmanly fears. When confidence is not founded on knowledge, it often leads to dangerous presumption, and foolish carelessness.

One advantage in the use of gas is its safety. When lamps or candles are employed, there is a danger of sparks falling and setting fire to the articles on which they are thrown, if at all combustible. But, if there be an ordinary degree of care

in the manufacture and use of gas, no means of artificial light appears so free from danger. When distressing accidents have happened, it has been from culpable inattention in the manufacture, or in the places where it was used to light. When the coal gas is mixed with the atmospheric air, it becomes most explosive; and when an ignited substance is introduced into the reservoir of gas, or an apartment containing this compound, a violent explosion will be produced.

One or two instances in which this has happened may be mentioned. At a small town, about thirty miles from London, it was found necessary to have a new gasometer for the supply of the inhabitants. It was accordingly fitted to the works, and filled with hydrogen. When this had been done, the person who superintended the works began to fear that some atmospheric air might be mixed with the coal-gas; and, to see if it were so, thoughtlessly opened an aperture, and set fire to the gas which issued from it. What was the consequence? The flame instantly mounted to the height of many feet, which so much alarmed him, that he made many attempts to extinguish it, and at last ordered that a piece of soft clay should be placed upon the aperture. Unfortunately his order was executed; the flame

was driven into the gasometer, and an instantaneous explosion was produced, which shattered the reservoir, blew one man into the air, and injured several others.

Another accident, from the combustion of the mixed gases, happened nearer to London, still more recently. It appears, that from some faulty part of the machinery, there was an escape of gas, which mixing with the atmosphere of the building in which the gasometer was contained, produced an explosive compound. A candle was incautiously taken into the impure atmosphere, and an explosion instantly followed.

The same effect may be produced in a room where gas is burned, but only from great inattention and carelessness. If the gas should be allowed to escape, by turning the stop-cock without applying a light, or only partly closing it when the light is out, (this latter is a neglect not uncommon,) a room will soon be filled with an injurious and combustible atmosphere, and the introduction of a flame would be exceedingly dangerous. This is the only accident that can possibly occur from the use of gas, unless the ignition of substances, from actual contact, is considered as another liability; but this attaches to every flame, however it may be produced. The assertion that the gas light is safer as a means of

illumination, in ordinary circumstances, than any other kind of combustion, is therefore fully justified.

The cleanliness of gas lighting is another circumstance very favourable to its general application. If the gas be well purified from the adventitious ingredients it contains when first formed, it may be burned for years in the same room, without in the least discolouring the articles in it, or even the ceiling. We know a medical gentleman, who has burned gas in his bedroom for the last four years, and it is of so pure a quality, that there is no perceptible difference between that part of the ceiling immediately above the light, and other places; but this is not common. When gas, after being burned for a short time, leaves a black stain upon the ceiling, the consumer has just cause of complaint.

The cheapness of gas-lighting is another excellent reason for its common adoption; and it has many advantages recommending its use in streets, and other exposed places.

A special advantage is obtained from the use of gas, in the greater intensity of its light, than that of any other artificial means of illumination. Several methods of estimating the degree of intensity possessed by different luminous bodies have been invented. Two circumstances which govern the intensity of light—the distance, and

the number and illuminating power of the rays, are worthy of notice.

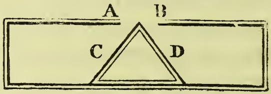
The intensity is, in the first place, inversely as the square of the distance. A familiar explanation may be given of this statement. If a board, one foot square, be illuminated by a candle at the distance of one yard, four feet square will be lighted at the distance of two yards, and at the distance of three yards, nine feet square. Hence, it will appear, that the same rays of light are successively diffused over a larger surface, the surface illuminated being according to the square of the distance. Now it is quite evident, that, if this be true, the intensity will be inversely as the square of the distance; for, as the distance increases, the rays are thrown over a larger surface, according to the same law. We may have proof of this in any place where there is a luminous body. As, for instance, we recede from a candle, lamp, or gas-light, the intensity decreases most rapidly; and though we might see to read the smallest type when close to the light, a large print could not be read at eight or ten feet distance.

The intensity of light given out by any substance during combustion, compared with that obtained by some other substance, must also depend on the proportional number and intensity of the rays, and the area of the illuminated sur-

face. A gas-light gives out a much more intense heat than a candle, for this reason; and the fact accounts for one of the advantages derived from its adoption, as a means of obtaining an artificial light.

Various instruments, called photometers, have been invented, to measure the intensity of light. None of them can lay claim to any degree of exactness; for they are only means by which the sense of sight is assisted. We cannot obtain a contrivance by which to measure the degree of illumination on a scale, in the same manner as to determine temperature by a thermometer. We can only judge of the proportional intensity between one light and another, by the influence they severally have upon the organ of sight, which is not able, under any circumstances, to judge of the amount of difference. An illumination which may appear very brilliant, and even oppressive to the eye, if we have been previously in darkness, will appear dull and gloomy, if we observe it after having seen a much more intense light. So, also, under ordinary circumstances, we are unable to judge how much more one substance is illuminated than the other, though the difference between them may be perceptible. To assist the eye in comparing the intensity of light, is all that can be done by a photometer.

The only instrument of this sort now to be mentioned, is that invented by Professor Ritchie. It consists of a rectangular box, open at both ends, coloured black in the interior, to absorb any light that may be thrown upon it, whether from reflection or otherwise. In the centre of the box, two pieces of looking-glass are fixed, at an angle of 45 degrees, as shown at C and D in the figure, presenting a sectional view of the



instrument, which is the appearance it would have if one of its sides were taken away. At the top of the box a narrow slit is made, which must be covered with tissue paper. Now, if it were required to examine the difference of intensity between two lights, say, for instance, a gas-light and a candle, one would be placed at one end of the instrument, and one at the other. The light of each will be reflected, the candle from C, the gas-light from D, on the tissue paper at A B. If they are placed at equal distances, that part illuminated by the gas will be much more intense than that which receives light from the candle. It must, therefore, be removed to a greater distance, until each half of the slit shall appear to be equally illuminated. The relative distances between the two luminaries must then be deter-

mined; and, by the law already stated—that the diminution of light is as the square of the distance, it will be easy to calculate the variation of intensity between the light of the candle and that of the gas.

An idea of the extent to which gas-lighting is carried in the metropolis alone, may be gathered from the following statement:—There are eighteen public gas-works, conducted by twelve companies: their capital amounts to upwards of £2,800,000, employed in pipes, tanks, etc. The revenue derivable therefrom, is estimated at £450,000 per annum. There are about 180,000 tons of coal used annually; there are 1,460,000,000 cubic feet of gas made; 134,300 private lights; 30,400 public lights; 380 lamp-lighters; 176 gasometers, several of them double, and capable of storing 5,500,000 feet of gas; and about 2,500 persons are employed, in various ways—a greater number than found employment when the old and bad lamps were used.

CHAPTER VI.

THE HAND BELL.

ANTIQUITY OF BELLS—PRODUCTION OF SOUNDS—SOUNDS CONDUCTED BY LIQUIDS, SOLIDS, AND GASES—MUSICAL SOUNDS.

Bells of a small size are, doubtless, of great antiquity. Pots, and other vessels, being more necessary in the service of life, would, of course, be made at a still more remote period; and it is probable that the observation of their giving forth a sound when struck, gave occasion to making bells in that form.

Small gold bells, intermixed with pomegranates, are mentioned in Scripture, as worn in the robe of the high priest, Exod. xxviii. 33, 34. Hand bells were used by the Greeks in camps and garrisons, and by the Romans, for various purposes. The large bells, used in churches, are said to have been invented by Paulinus, bishop of Nola, in Campania, about the year 400; and were probably brought into England soon after their invention. The employment of bells for domestic purposes is familiar to all. The substance of which they are made is called bell-metal: it is usually an

alloy of eighty parts of copper and twenty of tin. The Indian gong-metal is a similar alloy. An English bell, when analysed, was found to consist of 800 parts of copper, 101 tin, 56 zinc, and 43 lead. Zinc is specially employed in small shrill bells.

In the production of sound, three things are to be noticed: a sounding body, a conducting medium, and an organ of hearing. Sounds are, in all cases, occasioned by the vibration of some substance. When we ring the house bell, for example, we, in fact, put it into a state of vibration; and this is evident to the sense of touch; the same result is produced when a string is made to sound, and may be seen as well as felt. This vibratory motion is communicated to the air, or any other medium which surrounds the sounding body. A series of waves is thus produced, which extend in every direction.

Every one must have observed the effect produced by throwing a stone into water, or by a gust of wind passing over a field of standing corn. But it may be doubted whether persons generally have an accurate idea of what is signified by the term waves. If we stand by the sea shore, when the surface of the sea is ruffled, we may imagine the waves are advancing towards us, and it is a common expression, "The wave is coming." This is apparently the case; but, in truth,

there is no progressive motion. A wave is, as Sir John Herschel has said, a form and not a thing. If the waves were masses of water advancing toward the shore, there would soon be an accumulation of that fluid; but the motion is on the surface, upwards and downwards, not in a horizontal direction. That part of the water which is at one moment a ridge, at the next becomes a valley; yet it does not change its place relatively to the water surrounding it. A boat, in a rough sea, is tossed up and down, but has no motion over the surface; or if it has, the current, or tide, produces it, not the wave. Now, the effect produced upon air by a vibrating body, is supposed to be similar to that occasioned by wind passing over the sea, or, more properly, by a stone thrown into the water.

Air is the most common conductor of sound, but its capacity varies according to circumstances. In a vessel containing condensed air, the intensity of a sound is increased; in one exhausted of air, the sound is almost entirely lost. There is also a great difference in the conducting power at different times. It is a common remark, that sounds are more distinct at night than during the day; and this may be, in part, but not altogether, accounted for, by the stillness of the season. There is also a philosophical reason for the fact. Sound is never conducted with facility by any medium, but that

of uniform density. Take a tumbler, and place in it a little water, touch it gently on the edge with a spoon, and it will give a clear, distinct sound. Then add to the water some carbonate of soda and tartaric acid, making an effervescing liquid, and touch the edge of the tumbler again in the same way—a dull, heavy, leaden sound will now be produced. The reason of this evidently is, that the medium is of unequal density, for the carbonic acid gas is blended with the water, and the sound is stifled. This experiment suggests a reason for the greater distinctness of sounds during the night than day. In the day, the stratum of atmosphere surrounding the earth, is by no means of an equal density, for, in every place, there will be constantly currents of hot air rising, and cold ones descending; but, at night, an equality of temperature is produced, and sounds are conducted with greater facility.

Other gases are also conductors of sound, but the intensity varies. In hydrogen gas, sounds are scarcely audible; in carbonic acid gas, they are much louder than in atmospheric air. Liquids conduct sound, such at least as have been examined. Fishes, although unprovided with an external organ of hearing, certainly are conscious of sounds, and, therefore, water is a conductor. But the proof of this does not depend on that

fact, for experiments have been made by many philosophers, with a view to the determination of the velocity of sound in this medium; divers hear when under water, but are especially sensible of those noises which are made beneath its surface.

Many solids, also, have the power of conducting sounds. An experiment was made with a piece of wire six hundred feet long, and a noise produced at one end was distinctly heard at the other; and not only so, but two sounds were audible, one arriving after the other, for both the wire and the air acted as conductors. It is well known, that wood is a good conductor of sound; for the ticking of a watch placed at the end of a long piece of timber, may be distinctly heard at the other.

In order that solids should conduct freely, they must be homogeneous, and perfectly joined; if not, the sound will be hindered. Every one knows how different is the sound produced by striking a tumbler before, and after it is cracked, or a bell under the same circumstances; and if such an alteration is produced in the vibrating body, we may expect a similar one in a conductor.

Sounds are sometimes heard at very great distances, and even at heights above that at which the atmosphere is supposed to have the effect of refracting the rays of light. The meteor of 1719,

was sixty-nine miles above the level of the ocean, when it exploded, but produced a sound like that of a large cannon; and that of 1783, was fifty miles high, and moving at a rate of twenty miles a second, when it burst, and produced a rumbling sound. Even upon the surface of the earth, sounds are sometimes heard at a distance, much greater than might be imagined. Lieutenant Foster says, that he has conversed with a man over Port Bowen, which is a mile and a quarter across. It is well known that sounds are remarkably well conducted over still water and ice. The detonations produced during the eruptions of Tomboro, a volcanic mountain in Sumbawa, were heard at a distance of nine hundred and seventy miles—a statement that would be hardly credited, without the authority of sir Stamford Raffles.

The velocity with which sound moves depends on the nature of the conducting medium. In atmospheric air it moves at the rate of 1090 miles in a second; in water, of 4,708 feet. It seems scarcely necessary to remark that all sounds move with the same velocity; for, if this were not the case, there could be no means of judging distances by sound. When a man stands at the end of a room, in which various instruments are played, however great may be its length, his ear is not offended by a want of harmony, as it would be if

all sounds did not move with the same velocity. If some notes travelled faster than others, nothing but discord could be produced at any considerable distance. Instead of this, whatever may be the distance of the hearer from the orchestra, he is as able to judge of the performance as one who stands close to the musicians.

The organ of hearing is one of the most sensitive and useful of all the senses. The eye is the most excursive, and perhaps the most valuable to us; yet there are many instances in which it is insufficient to warn us of danger. Looking at man only as a being interested in the preservation of his present life, the organ of hearing is of importance; but when we consider him as an intellectual and responsible being, how greatly is its value increased in our estimation. Without the organ of hearing, we can gain no advantage from society; and the voice of our fellows, which is so efficient in reproof and encouragement, would be unknown to us. The ear is the medium of many of our purest enjoyments, and without it, the human race could have no means of mutual communication.

We are accustomed to make a distinction between the sounds we hear. The most general classification is, into noises and musical sounds. A noise is the result of irregular impulses; a

musical sound, on the other hand, is produced by a series of regular impulses. It is imagined that less than sixteen impulses would not occasion an audible, continuous sound. Noises are of various kinds, and we are accustomed to distinguish them with great accuracy by the use of particular terms, but it is not easy to draw the distinction in words; we speak of a crack, explosion, rumble, crash, and so on: and to each term, we give a fixed and specific meaning.

In a musical sound there are three things to be considered: the pitch, the intensity, and the quality. The pitch will depend on the number of vibrations. Each note of the gamut is produced by a certain number of vibrations; and if less or more, it would be lost. The whole art of tuning an instrument is to arrange all its parts, so that each one may have such a number of vibrations as shall produce the tone required. The intensity of the sound is in the greater or less violence of the impulse. We may obtain the same note so loud as to be heard over a large room; or so soft, that it shall be scarcely audible to the persons who are nearest the player. The quality of the sound is its regularity or abruptness.

Any two notes, struck at the same time, are not necessarily in harmony. There are some which produce discord. An accurate ear can

detect, even in a large band, a single discord. When the vibrations, producing any two or more notes, are in simple proportions, harmony is the result. The most simple concord is that called an octave, and in this, the vibrations are as one to two; when as three to one, a twelfth is produced; three to two, a fifth; and three to four, a fourth. When the number of vibrations are in a high proportion, such as one to seven, or seven to six, discord is the result.

There are three classes of musical instruments: vibrating strings, pipes, and tubes; and vibrating plates, or bars.

The violin, violincello, piano, harp, guitar, and many other instruments, are but different arrangements of strings, which, being made to vibrate, produce musical sounds. In the first two, a bow is used to put the strings in a state of vibration; in the piano, a small hammer strikes upon the string; and in the last two, vibration is effected by the finger of the player. The pitch, or note, will depend upon three circumstances: the length of the string, the density, and the weight by which it is stretched. In the violin, the length of the vibrating string is changed by the pressure of the finger upon it; in the harp and piano, the strings are of different lengths. The density, or thickness of the string will also cause an alteration of

tone. In the violincello, for instance, there are four strings, and all of different thickness. The weight by which the string is stretched, or, in other words, the tension, must also be considered. As weights would be inconvenient in use, screws are generally employed; and by turning these in one direction or the other, tension is regulated.

Pipes and tubes may be employed for obtaining musical sounds, in a variety of ways. We have different examples in the flute, clarionet, organ, and other instruments; but it is to be remembered, that the sound is not produced by the vibration of the substance of which the tube is formed, but by the vibration of the column of atmospheric air; and the pitch will depend on its length.

CHAPTER VII.

GOLD AND SILVER.

USE OF PAPER MONEY—STANDARD OF VALUE—THE LOVE OF MONEY—EXPLOSIVE COMPOUNDS—TOILS OF ALCHYMISTS—SMELTING AND AMALGAMATION.

Gold and silver are frequently seen, yet their comparative scarcity have given to them a greater value than most other mineral substances. They are used in nearly all civilized countries, as a circulating medium; and a value is attached to them in others.

In many nations, the national bank circulates paper with a printed form, by which the parties issuing, promise to pay a certain amount to the owners of these papers whenever presented for that purpose. Bank of England notes are of this kind, and are current in all places where there is a confidence, that the bank directors can pay what they have promised. The notes are not, in themselves, of any real value; still, it is a great convenience to have them received generally, as the representative of a certain amount of money. It is true, there is no value received; but as long as the notes can be converted into gold, an intrin-

sically valuable substance, they are suitable mediums of commerce.

Supposing that in some large transaction, it were necessary for one merchant to pay another the sum of several thousand pounds, and there were no notes, the whole amount must be given in sovereigns, which would not only be very heavy and inconvenient to carry, but considerable time must be lost in counting over the coins. It would, in fact, be almost impossible to conduct the commerce of any country without some circulating medium of the kind now mentioned. In this country, however, gold is the standard to which all values are referred. If we speak of the value of a note, we say it is worth five, ten, twenty, or some greater number of sovereigns; and a book is worth a certain part of a sovereign; as, for instance, a shilling, twenty of which are said to have a value equal to one sovereign.

Money, after all, has only one real use: it enables us to provide those things which are necessary for the sustenance and comfort of life. As such, it is the duty of every man to make some attempts to obtain it, that he may provide for his own wants, and the temporal happiness of those dependant on him. But "the love of money," says the Scripture, "is the root of all evil." It is a disposition of mind which may excite all the

worst principles of our depraved nature. A miser is the most pitiable, as well as the most despicable of men. It is scarcely possible to imagine a condition more fraught with danger, than that of the individual who has set his heart resolutely on the acquisition of money. The probability is, that he will be induced to take dishonest means to secure his object. Yet how few are there who can utter with sincerity, the wish comprehended in the prayer of Agur: "Give me neither poverty nor riches; feed me with food convenient for me: lest I be full, and deny thee, and say, Who is the Lord? or lest I be poor, and steal, and take the name of my God in vain," Prov. xxx. 8, 9.

Men are now frequently estimated by their possessions, and not by their characters. It matters but little, in the view of the world, how riches have been obtained: their possession is sufficient to exalt him who has them. It is not thus that the great Head of the church owns his followers; and Christians must have a higher standard.

Gold is the heaviest of all metals, except platinum; and is so ductile and malleable, that it may be beaten into leaves one-two hundred and eighty thousandth part of an inch thick. It is not acted upon by the atmosphere, water, or even the acids; nitro-muriatic acid and chlorine are the only substances which will dissolve it. Gold

leaf, introduced into chlorine gas, takes fire and burns. Its presence, when in solution, is detected by dropping into the liquid the green sulphate of iron, when a brown precipitate is produced. When ammonia is made to combine with the oxide of gold, a very dangerous compound is formed, called fulminating gold. This substance explodes violently when its temperature is raised, and also when there is a slight friction. Accidents have often occurred from a careless use of this and similar substances. Young persons are sometimes found trifling with dangerous compounds; and we cannot, therefore, too strongly impress upon them the folly of such conduct, for dangerous, or even fatal consequences may be the result.

Gold has the property of combining with other metals. It forms a most excellent alloy with a small quantity of copper; for the compound is harder than the pure metal, and retains its lustre. The gold coin of this country consists of gold, copper, and silver: in every twelve parts there are eleven of pure gold.

When chemistry first attracted the attention of inquiring men as a science, there were many who devoted all their attention and time to the vain hope of discovering a method of making this precious metal. It was generally supposed, at this period, that the baser metals might be transmuted into gold.

In the old alchymical works, rules are given for this purpose; but they are expressed in such enigmatical terms, that it is quite impossible to understand what is meant by their authors. For very many years, a vain search for a method of transmuting the baser metals into gold, and for an universal elixir, capable of curing all diseases, was the only employment of the chemist; and even in the present day, there are some persons who pretend to have discovered the art. In some modern works, as in the Life of Dr. Clarke, for instance, curious accounts are given of the production of gold, from lead and other common metals, for which it is not easy to account. The following is one of these, from Major Kinneir's Travels in Armenia and Koordistan.

"A few days before my arrival at Bassora, in August, 1814, Mr. Colquhoun, the acting resident in that place, received a message from an Arabian philosopher, in order to communicate a most important secret. Mr. C. consented; and next morning the mysterious stranger was introduced to him: embracing the knees of the resident, he said he was come to supplicate the protection of the English from the cruel and continued persecution of his countrymen, who, understanding that he had the power of transmuting the baser metals into gold, daily put him to the torture to

wring his secret from him. He added, that he had just made his escape from Grane, where he had long been starved and imprisoned by the sheik; and that he would divulge every thing he knew to Mr. Colquhoun, provided he was permitted to reside in the factory. My friend agreed to receive him; and, in return, he faithfully promised to afford a convincing proof of his skill. He accordingly retired, and soon afterwards returned with a small crucible and chafing dish of coals; and when the former became hot, he took four small papers, containing a whitish powder, from his pocket, and asked Mr. Colquhoun to fetch him a piece of lead. The latter went into his study, and taking four pistol bullets, weighed them, unknown to the alchymist. These, with the powder, he put into the crucible, and the whole was immediately in a state of fusion. After the lapse of about twenty minutes, the Arabian desired Mr. Colquhoun to take the crucible from the fire, and put it into the air to cool. The contents were then removed by Mr. Colquhoun, and proved to be a piece of pure gold, of the same weight as the bullets. The gold was subsequently valued at ninety piastres in the bazaar."

It is difficult to know what can be said to this curious story; for it appears singular, that a poor Arabian should present ninety piastres to an

English resident for protection. He never returned to Mr. Colquhoun, for he was carried off by the sheik of Grane, who broke into his house the same night.

Gold is chiefly found in Peru and Brazil; it is sometimes obtained from Siberia and Hungary. In many of the African rivers it has been discovered; in the province of Sonora, it is said, the Spaniards found a plain, fourteen leagues in extent in which they found wash-gold, some of the masses of which weighed seventy-two ounces. A quantity of immense value was collected here in a very short time. To obtain this metal, all the European adventurers, who visited America soon after its discovery, were not slow to commit any enormity. Slavery and death were the attendants upon every step in discovery; and the cupidity of the early navigators can only be compared with the rapid fall of the nations most intimately connected with the Europeans who first visited the shores of America.

Silver is a white metal, exceedingly ductile and malleable, heavy and sonorous. It is found in many countries, and in various states: native silver is chiefly obtained from the mines of Potosi; and is occasionally met with in copper mines. Sulphuret of silver, and oxide of silver, are more common. The silver mines of Mexico and Peru

are the richest in the world. Baron Humboldt states, that in the space of three centuries, 316,023,883 pounds troy of the pure metal were obtained; and that the quantity would be sufficient to form a solid globe of silver, 91,206 feet in diameter. A large proportion of silver is frequently alloyed with lead. There is one mine, in the county of Antrim, in Ireland, so rich that one pound of silver is obtained from every thirty pounds of lead ore. The principal use of silver is for coining; but it is also used for many ornamental and useful articles, such as spoons, candlesticks, tea-pots, and forks; but, as it is a comparatively soft metal, it is commonly alloyed with copper.

The indelible ink for marking linen and cotton, is nothing more than a solution of nitrate of silver with a little gum water. The nitrate of silver, when melted and run into moulds, is sold by the chemists as lunar caustic. Dr. Henry states, that the indelible ink may be prepared by dissolving two drachms of lunar caustic, the purity of which is, for this purpose, important, and one drachm of gum arabic, in seven drachms of distilled water, colouring the liquid with a little China ink. The preparatory liquid for moistening the cloth, is made by dissolving two ounces of sub-carbonate of soda, and two drachms of gum arabic, in four ounces of water.

There are two methods of purifying the ores of the precious metals, that is, separating the metals, from the substances with which they are combined. One is called smelting, or roasting; the other, amalgamation: it is to the latter we must chiefly confine our attention. An amalgam is a metallic compound. It was early known that mercury had the property of uniting with the precious metals; but it was, according to Humboldt, first applied to useful purposes in the amalgamation of silver, in Mexico, about the year 1557. Mr. Vivian supposes the first application of the process in Europe, to have been at Konigsberg, in Norway, about 1738.

CHAPTER VIII.

THE TIME-KEEPER.

THE HOUR-GLASS—ITS PHILOSOPHY—FIRST MENTION OF A DIAL—RECKONING OF DAYS AMONG MANY PEOPLE—STRUCTURE OF THE CLOCK—MECHANISM OF THE WATCH—THE CHRONOMETER—IMPROVEMENT OF TIME.

For a long period, the course of time was marked by the flowing of sand in the glass. The time-keeper was, in consequence, called the hour-glass. It may still be seen in many a cottage; and sometimes on the table of the teacher, or lecturer. The half-hour glass is employed on board ship; and the three-minute glass is well known under the appellation of the egg-glass, to regulate the time for the boiling of eggs. The shape is not a matter of great consequence; but the form generally adopted, is that of two pear-shaped vessels, joined at their smaller ends. These vessels are blown of equal size, and the sand is placed in one of them, before the other is joined to it. The best sand, is that called silver-sand. The size of the opening determines the rapidity of the flow of the sand. Nor let this inartificial machine on any occasion be despised; it measures time far more accurately than is usually imagined; and

experiments of late years have shown that its philosophy is worthy of attention.

It is a remarkable fact, that the flow of the inclosed sand is perfectly equal, whatever be the quantity contained in the glass, at any period of its flowing. In other words, it runs just as fast when the upper cone is nearly full, as it does when it is nearly empty; nor is there, from first to last, any difference in the rate of its course. This is contrary to our expectation. We should be disposed to conclude, that when the glass was full of sand, the lower particles would sustain a greater pressure from the mass above, and therefore be more swiftly urged through the aperture, than when only a quarter full, and near the close of the hour. But that it is otherwise may be proved by a simple experiment. Take a quantity of silver-sand, dry it on a hot stove-plate, and sift it through a tolerably fine sieve, carefully removing any lump of clay or stone. Take also a tube of any length or diameter you please, closed at one end; in this make a small opening, say of an eighth of an inch, and, placing the finger over this, fill the tube with the sand. Now hold the tube steadily, or fix it up in any way, and removing the finger, let the sand flow into a measure—for example, a graduated glass measure, such as is found in many a family—for any given

time, say a quarter of a minute. Note the quantity which is now obtained. Then let the tube be only a half, or a quarter full of sand, and begin to measure again for a like time, the same quantity of sand will flow; and if the sand in the tube be violently pressed, the flow of it will not in the least degree be hastened. This will be fully proved if the tube be kept steady, and the account be accurate. And now for the philosophy of the hour-glass: for all this admits of a satisfactory explanation. Sand, if allowed to fall quietly on any surface, will form itself into a conical heap, having an angle of about thirty degrees. Look at the lower cone of the hour-glass, or at the sand which has fallen through the opening in the tube; or at a load of dry sand thrown from a cart, or barrow; or at some sifted through a screen, and this will be clearly perceived. A slight variation may occur in the latter case, but the angle is very nearly the same.

Sand thus falling at a fixed angle, it will be seen that when poured into a tube, it must fill it with a succession of conical heaps; that all the weight which the bottom of the tube sustains is only that of the heap which first falls; and that the succeeding heaps are thus prevented from exerting any perpendicular pressure on the bottom. When pressure is applied to the top of

the sand it is only transmitted laterally, or sideways, and that to a very little extent. The lowest heap that has its flow, yields not to any pressure from above. Here, then, is the reason for the equal flow of the sand.

Proof of this may easily be had: take a tube open at both ends, for example, and bring it in contact with the bottom of a small cup floating upon water. Fill up the tube with sand, none of it will run out into the cup; and that there is no pressure from above, appears from the cup continuing to float. It sustains no weight but that of the first heap; now draw away the tube, and the sand, obeying the law of gravitation, rushes into the cup, which sinks because of the weight. Again: take a common syringe, pour some sand in, and try to push it out, and you will not succeed. Repeated efforts will show that to do so is impossible: the tube will sooner burst laterally, than allow it to pass.

Naturalists have been recommended to shoot birds with a charge of fine sand, so that their plumage may not be damaged, as it is by small shot. But what is shown by the experiment just mentioned? That the charge of sand would resist the force of the gunpowder; violently strain the barrel, and, perhaps, burst it. The use of sand, even in a small quantity, must be a hazardous

experiment. The power which sand has of resisting the force of gunpowder is evident from the practice of engineers in blasting rocks. For this purpose a hole is drilled in a rock, and at the bottom a charge of powder is laid. A long match, or reed, filled with gunpowder, is then put down the hole, and around this sand is poured, so as to fill up all the unoccupied parts. A train is now laid and fired, and presently the explosion takes place, and the rocks are rent. But, notwithstanding, the loose column of sand is not blown out of the hole, but keeps its place. Is there not then much to notice in the hour-glass? Perhaps, no other natural force on the earth produces, by itself, a perfectly uniform movement, except this falling sand. In other cases, friction is an obstacle—here it is the regulating cause; in others, the air presents a formidable resistance—here it must be so feeble, as to be altogether insensible.

The first mention of a dial is that of king Ahaz, 2 Kings xx. 11. We can thus trace its antiquity; but no account is given of its origin or form. That it should bear the name of the king is remarkable; but it might be either imported from abroad, or made after the pattern of one he had seen in his travels. He sent from Damascus a pattern of an altar he had

beheld in that city, and his dial might have been a case of the same kind. The Jews had most probably a popular method of measuring time by the length, indications, and shadows of objects, and which continues in use among the peasantry of the most cultivated nations. They were not remarkable for their invention, and therefore it is not likely to have originated with them.

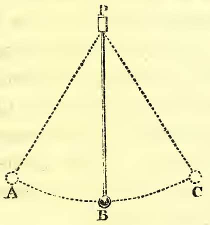
The setting up of pillars in the midst of an open area, on the pavement of which were marked different lines, so that the shadow might mark the passing of time, was a practice of very early date. Some have contended that the famous obelisks of Egypt were intended for the same purpose. The use of pillars in this way, in Greece and Italy, is beyond dispute; and it is most likely, that when Augustus applied to this purpose the two obelisks, which he removed from Egypt to Rome, he merely continued them in their former use.

Not very long ago a curious instrument was in use in our own country. It was a brass ring, with the hours marked inside, and on the outside a sliding strip with a small perforation for the sun's rays to pass through, while the instrument was held suspended by a string. It was carried about in the pocket by many, whose successors find a silver watch much more useful.

Among the changes which have passed, within

the memory of many of the aged, are those in reference to time-keepers. There was once, for instance, a tall grave-looking box, having a circular glazed hole in the door, and only aiding the inquirer by an hour hand. To this succeeded one with a brass face, with the silver hour circle, and two steel pointers. And now we see a handsome case, the beautifully painted dial, the hands of brass, and an index directing to the seconds. German clocks, having wood or brass wheels, are common in humble circumstances; while time-keepers of great variety and elegance may be observed in use among the higher ranks. A brief account of the structure of a clock may be interesting to many.

The common pendulum is a heavy ball, attached to a slight cord, or thread, which may be suspended to some fixed point. If we place the



pendulum P B in any position out of the perpendicular, as P A, and let it fall freely, it will descend to B; and passing this point, will ascend on the other side to C, describing ar arc B C, equal to the arc A B: it will then begin to ascend, and passing B, ascend

again to A. It is scarcely necessary to explain the cause of this motion, for it is evident that when the pendulum descends, its velocity increases till it reaches B, and the accelerated motion it has obtained is sufficient to carry it upwards to C.

The time occupied in an oscillation, when it is not very considerable, is the same, whatever may be its length. This property is said to have been discovered by Galileo, the celebrated philosopher, who improved the telescope, and discovered the satellites of Jupiter. He was sitting one evening in the church of Pisa, and after the great chandelier was lighted up, it was left swinging, which attracted the attention of the youthful philosopher; and he, at the same time, observed that the vibrations were performed in equal times. By a subsequent examination, he established the truth of his observation, and the use of the pendulum for the measurement of time.

Another important principle in relation to the pendulum, is, that the time occupied in an oscillation is not dependent on the weight of the ball, the substance of which it is made, or its shape, except so far as regards the resistance of the air. This law is easily demonstrated, for if we take balls of different substances and sizes, being careful that the pendulums are of equal length, and

cause them to vibrate together, it will be seen that the time occupied in a vibration will be the same. Gravity, in its action upon a pendulum, causing it to oscillate, exerts its influence upon each atom of the matter which composes the ball; and therefore a single atom, suspended to the end of a thread, would oscillate with the same velocity, as any number of atoms combined together in a body. So, also, an atom of iron would vibrate with the same velocity as an atom of platinum, or of gold, since all masses, whatever their nature, oscillate in the same arc, with the same velocity.

Pendulums have been spoken of as vibrating in the arc of a circle; but there is a mathematical curve, called a cycloid, and if the bob of a pendulum should be made to vibrate in it, its oscillations would all be performed in equal times, whatever the length of the arc. There are some very remarkable principles, which might be mentioned, in reference to this curve. Of all paths not in a straight line, the cycloid is that in which the body can pass the most readily from one point to another. The right line is, of course, the shortest path between two bodies; and if a man in a balloon would throw a stone to some point on the earth in the shortest path, he would cause it to take the direction of a right line; but if he wished to throw the stone in the line of shortest descent,

it must be made to move in the cycloidal curve, for it would not only reach its destination sooner, but it would strike the object with greater energy. The study of mathematics has taught man this truth; and instinct has taught the falcon to fly in the cycloidal curve: in consequence of which, when attacking their prey, they possess so great a velocity, and strike with so great a force.

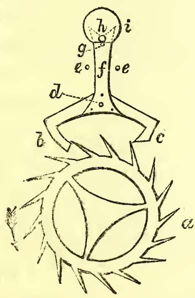
As the oscillations of the pendulum vary with its length, a certain length is required that it may beat seconds, or, in other words, vibrate sixty times in a minute. The length required in the latitude of London, is a little more than thirty-two inches; but a pendulum that would beat seconds in London, would not do so in Paris.

The increase, or decrease, of temperature has a considerable influence on the oscillation of a pendulum. A bar of metal which, when cold, will pass easily between two uprights, will not do so when heated red hot, for heat expands solid metallic bodies. For this reason, a pendulum which beats seconds in a low temperature, would cease to do so if taken into a hotter climate, for its length would be increased. This is a fact of great importance in clock-making; and mechanics have invented various methods of compensating for this alteration in the length of the pendulum. Sometimes this has been done by making the rod

of the pendulum of a substance that would not expand appreciably by heat; and sometimes by contrivances which correct the increase of length that results from a change of temperature. The length of a rod of dry wood is not altered by a change of temperature; and it would be the best possible contrivance, if it could be perfectly protected from the action of the air. It is, however, in a considerable degree, defended from moisture, when rubbed over with bees' wax; and makes the most accurate pendulum of this sort, when thus prepared.

Another important part of a clock is the escapement, of which the following is a figure.

a, is the scape-wheel, moving in the direction of the arrow; *b c*, the pallets, whose centre of



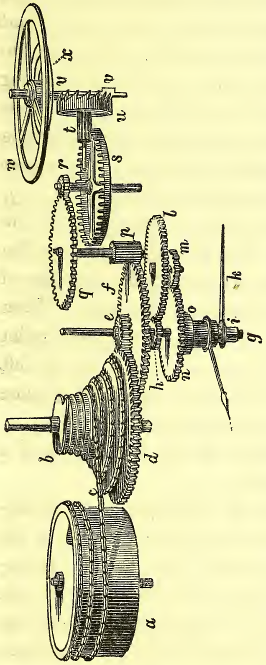
motion is *d*; to the pallets is pinned the lever *f*, in which is the guard-pin *g*, pointing upwards from the lever *f*; the roller *i*, is fixed on the axis of the balance, and stands just above the lever *f*, having a piece cut off from its circumference, to allow the guard-pin, *g*, to pass and repass the roller, which it does when the escape takes place;

h, is a ruby pin, fixed in the roller, and pointing downwards through the notch in the end of the lever *f*. When the balance is quiescent, the pin *h*, is in the notch in the end of the lever *f*, and the guard-pin *g*, in the position shown in the figure; where a tooth of the scape-wheel is acting upon the pallet *b*, which causes the balance to vibrate, the guard-pin *g*, proceeds a short distance to the right of its present position, and the lever is prevented from returning, by the guard-pin *g*, coming in contact with the circular edge of the roller. The effect of the locking is to retain the pin *g*, at a very small distance from the edge of the roller during the vibration of the latter. When an impulse is given by a tooth to the other pallet *c*, the lever *f* impels the ruby pin *h* to the left hand, where precisely the same effects take place with regard to the guard-pin *g*, etc.

We may now proceed to the mechanism of a common vertical watch.

The cut, on page 97, represents the wheel-work without its frame, as it would appear if the dial (which is here omitted) were turned downwards. *a*, is the barrel; *b*, the fusee; *c*, the chain by which motion is communicated from the barrel to the fusee; on which is the great, or fusee wheel, *d*, acting on the centre wheel pinion *e*, on which is riveted the centre wheel *f*; the arbor of

the pinion *e*, being prolonged through the plate of the watch as far as *g*: the centre wheel *f*, and its pinion *e*, revolve in an hour. Upon that part of the arbor *e* which is on the outside of the plate, or frame, is placed the cannon pinion *h*, which has a hole quite through it, for the reception of the centre wheel arbor, on which it turns spring-tight. The cannon pinion is secured in its place by a small pin through the end of the centre-wheel arbor *g*; the end *i* of the pinion being squared to receive the minute hand *k*; the cannon pinion has twelve leaves acting in the minute-wheel *l*,



of forty-eight teeth, causing the latter to revolve once in four hours. Concentric with *l*, and

attached to it, is its pinion m, having a hole through their common centre, through which passes a stud, fixed on the plate; through the end of which, near letter m, should be put a small pin, to retain the wheel in its proper place, but which is very frequently omitted. The pinion m, having fourteen leaves, drives the hour-wheel n, of forty-two teeth, once round in twelve hours, and which is placed over the cannon pinion by its socket o, which has a hole for the cannon pinion to pass through; on this socket is fixed the hour-hand. By this arrangement, the cannon pinion h, minute-wheel l, pinion m, and hour-wheel n, together with the hands, can all be turned backward, or forward, without affecting the interior mechanism of the watch, simply by the application of a key to the squared end of the cannon pinion. The assemblage of wheels, etc., thus put in motion, is called the motion-work of the watch; that between the plates, the movement—the description of which we will now continue. The centre-wheel f gives motion to the third wheel-pinion p, to which is attached the third wheel q, acting upon the contrate wheel-pinion r, on which is placed the contrate-wheel s, acting in the pinion t, of the balance-wheel u, which is also called the scape-wheel: v v, are two small levers, called pallets, which project from, and form part of, an upright staff or spindle, and

are acted upon by the teeth of the balance-wheel, so as to cause an alternating motion in the balance *w*; *x*, the pendulum-spring, also called the regulating-spring, and hair-spring.

The number of kinds of artificers concerned in constructing a good watch, will, perhaps, be surprising; especially when to this are added the amount of positive labour which the materials forming each piece must undergo, before it comes into the hands of the persons thus employed. The following table will convey some idea of this point:

	Number of pieces.	Trades employed.
1. Pillars	4	1
2. Frame	4	1
3. Cock and potence	2	1
4. Barrel and arbor	3	1
5. Going fuzee	14	2
6. Wheels	4	1
7. Pinions	4	2
8. Stop stud	1	1
9. Stop and spring	3	1
10. Click and racket	3	1
11. Motion	16	2
12. Jewels, (five holes)	28	2
13. Cap	3	2
14. Dial	5	3
15. Index	1	1
16. Escapement	13	3
17. Compensation balance	9	1
18. Case	3	1
19. Pendant	2	1
20. Case-joint	6	1
21. Case-spring, etc.	4	2
22. Main-spring	1	2
23. Chain	826	3
24. Hands	3	1
25. Glass	1	1
Total of pieces	963	38

Beside the foregoing, there is an engine turner, an engraver, a gilder, and an examiner, making a total of forty-two trades employed.

A chronometer is a watch of peculiar construction, and great perfection of workmanship, used for determining geographical longitudes, or other purposes, where time must be measured with extreme accuracy. The chronometer differs from the ordinary watch in the principle of its escapement; and is so constructed, that the balance is entirely free from the wheels, during the greater part of its vibration; and also in having the balance compensated for variations of temperature. Marine chronometers generally beat half-seconds. The pocket chronometer does not differ in appearance from the ordinary watch, excepting that, in general, it is a little larger. Chronometers are of immense utility in navigation; and ships going on distant voyages, are usually furnished with several, for the purpose of checking one another, and also to guard against the effects of accidental derangement in any single one. The accuracy with which some of the better sort of chronometers have been found to perform, is truly astonishing: the error, in a twelvemonths' voyage, not exceeding two or three seconds.

The most remarkable time-keeper in the world, is that in connexion with the Royal Observatory

at Greenwich. On the eastern turret of the principal building is a ball, five feet in diameter, which falls down a mast at a certain time every day. A few minutes before one o'clock, a person duly appointed, takes a chronometer, and at the precise moment of one, directs that the ball should be dropped suddenly, when it resumes its former position at the bottom of the mast till the following day. So satisfactory is the performance of the machinery that the error of letting off the ball seldom amounts to three tenths of a second.

The exact time of one o'clock is thus clearly made known; and the captains of ships within sight of the Observatory, may determine accurately the error and rate of their chronometers: such aid is to them of vast importance, as, by these means, they generally determine the position of their ships, when traversing the pathless waters.

The various subjects thus brought before us, ought not to be considered, without real benefit. How solemn are the thoughts connected with the passage of time! We lose much that is profitable, from our being commonly so insensible to its lapse. Suppose, for a moment, it could become visible, or that some visible object could bring it clearly to our sight. Were there, for instance, a transparent vessel containing water, from which one drop passed after another; and a voice from

heaven told us, that when the last drop was gone, we should die: should we not sometimes look with solemn interest on that vessel, and ponder with salutary emotion the lessening of its contents? Why, then, do we not consider the corresponding reality which actually exists, though such a mode of bringing it before us has been denied? The lapse of every moment, leaves one moment less; the lapse of every day, leaves us one day less; the lapse of every year, leaves us one year less—one year less for the duties of this life—one less for preparing for another. And yet with what prodigality have we wasted time! Wasted time, for which many would have given worlds, had they possessed them, for the hours we so wilfully throw away. Wasting it, when others were devoutly improving the very moments we lost, for their own soul's welfare, and for the advantage of others.

Truly has it been said:—

I asked the glad and happy child
  Whose hands were filled with flowers,
Whose silv'ry laugh rang free and wild
  Among the vine-wreath'd bowers;
I crossed her sunny path and cried,
  "When is the time to die?"
—"Not yet! not yet!" the child replied,
  And swiftly bounded by.

I asked the maiden: back she threw
  The tresses of her hair,

Grief's traces o'er her cheeks I knew,
  Like pearls they glistened there;
A flush passed o'er her lily brow,
  I heard her spirit sigh,
—"Not now," she cried, "Oh no, not now!
  Youth is no time to die!"

I asked a mother, as she pressed
  Her first-born in her arms,
As gently on her tender breast
  She hushed her babe's alarms;
In quivering tone her accents came,
  Her eyes were dim with tears;
—"My boy his mother's life must claim
  For many, many years."

I question'd one in manhood's prime,
  Of proud and fearless air;
His brow was furrowed not by time,
  Nor dimmed by woe and care;
In angry accents he replied,
  And flashed with scorn his eye—
"Talk not to me of death," he cried,
  "For only age should die."

I questioned age, for whom the tomb
  Had long been all prepared;
For death who withers life and bloom,
  This man of years had spared.
Once more his nature's dying fire
  Flashed high, and thus he cried—
"Life! only life is my desire!"
  Then gasped, and groaned, and died.

I asked a Christian—"Answer thou
  When is the hour of death?"
—A holy calm was on his brow,
  And peaceful was his breath;

And sweetly o'er his features stole
A smile, a light divine;
He spoke the language of his soul—
"My MASTER's time is mine."

Be it ours henceforth to redeem the time. As our first act, it becomes us to repair with deep humiliation of spirit to the throne of God, entreating pardon for the loss of opportunities never to return, through the Divine Redeemer who died "the just for the unjust, that he might bring us to God." And throughout our future course, be it ours to set on the days, or hours, or moments that remain, their real value. Time cannot be counted in silver, or gold, or gems. The earth has no gauge, or weight, or balance, to determine its worth. It must be estimated in connexion with our own souls' salvation, which can only take place in this world; and with the benefit of others, which can only be promoted by our efforts on this side eternity. So teach us, O Lord, to number our days, that we may apply our hearts unto wisdom: the wisdom of personal religion—the wisdom of winning souls for Christ!

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